BMS INSTITUTE OF TECHNOLOGY & MGMT.

Yelahanka, Bangalore-64

Department of Electrical & Electronics Engineering

VII SEMESTER

POWER SYSTEM SIMULATION LABORATORY
17EEL76

LABORATORY MANUAL

NAME OF THE STUDENT : ....

BRANCH : ....

UNIVERSITY SEAT NO. : ....

SEMESTER & SECTION : ....

BATCH : ....

Vikram Chekuri
Laboratory In Charge

HOD

Vision of the Department

To emerge as one of the finest Electrical & Electronics Engineering Departments facilitating the development of competent professionals, contributing to the betterment of society.

Mission of the Department

Create a motivating environment for learning Electrical Sciences through teaching, research, effective use of state of the art facilities and outreach activities.

Program Educational Objectives:

Graduates of the program will,

PEO1	Have successful professional careers in Electrical Sciences, and IT enabled areas and be able to pursue higher education.
PEO2	Demonstrate ability to work in multidisciplinary teams and engage in lifelong learning.
PEO3	Exhibit concern for environment and sustainable development.

Program Outcomes:

After the successful completion of the course, the graduate will be able to,

PO1	Apply knowledge of mathematics, science and engineering principles to the solution of engineering problems in electrical and IT enabled areas.
PO2	Identify and solve complex engineering problems using first principles of mathematics and engineering sciences.
PO3	Design system components and solve complex engineering problems that meet specific societal and environmental needs.
PO4	Conduct experiments, analyse, and interpret data to provide valid conclusion
PO5	Apply appropriate modern engineering tools to complex engineering activities with an understanding of the limitations.
PO6	Demonstrate understanding of societal health, safety, legal and consequent responsibilities relevant to the professional engineering practice.
PO7	Understand the impact of engineering solutions in a societal context and demonstrate the knowledge of and need for sustainable development.
PO8	Understand social issues and ethical principles of electrical engineering practice.
PO9	Function effectively as an individual and as a member or leader in diverse teams to accomplish a common goal.
PO10	Communicate effectively with diverse audiences and be able to prepare effective reports and design documentation.
PO11	Demonstrate knowledge and understanding of engineering and management principles and apply these as a member and leader in a team to manage projects in multi-disciplinary environments.
PO12	Recognize the need to engage in independent and lifelong learning in the context of technological change.

DO'S and DON'T'S in Power System Simulation Laboratory

DO'S

- Sit down and wait for teacher's instruction.
- Make sure your hands are clean and dry when you use the computer.
- Report any problems with your computer to the teacher.
- Shut down the computer properly.
- Keep the lab clean and tidy.

DON'T'S

- Do not touch, connect or disconnect any plug or cable without the Faculty /laboratory technician's permission.
- Do not open the system unit casing or monitor casing particularly when the power is turned on.
- Do not misbehave in the computer laboratory.
- Do not plug in external devices without scanning them for computer viruses.
- Always maintain an extra copy of all your important data files.
- Do not take food or drinks to the lab.
- Avoid stepping on electrical wires or any other computer cables.
- Do not install or download any software or modify or delete any system files on any lab computers.

B.E ELECTRICAL AND ELECTRONICS ENGINEERING (EEE)
CHOICE BASED CREDIT SYSTEM (CBCS)
SEMESTER - VII

POWER SYSTEM SIMULATION LABORATORY

Subject Code	17EEL76	IA Marks	40
Number of Practical Hours/Week	03	Exam Hours	03
Total Number of Practical Hours	42	Exam Marks	60

Credits - 02

Course objectives:

- To explain the use of MATLAB package to assess the performance of medium and long transmission lines.
- To explain the use of MATLAB package to obtain the power angle characteristics of salient and non-salient pole alternator.
- To explain the use of MATLAB package to study transient stability of radial power systems under three phase fault conditions.
- To explain the use of MATLAB package to develop admittance and impedance matrices of interconnected power systems.
- To explain the use of Mi-Power package to solve power flow problem for simple power systems.
- To explain the use of Mi-Power package to perform fault studies for simple radial power systems.
- To explain the use of Mi-Power package to study optimal generation scheduling problems for thermal power plants.

Sl. No	Experiments
1	Formation for symmetric π /T configuration for Verification of $AD-BC$=1, Determination of Efficiency and Regulation.
2	Determination of Power Angle Diagrams, Reluctance Power, Excitation, Emf and Regulation for Salient and Non-Salient Pole Synchronous Machines.
3	To obtain Swing Curve and to Determine Critical Clearing Time, Regulation, Inertia Constant/Line Parameters /Fault Location/Clearing Time/Pre-Fault Electrical Output for a Single Machine connected to Infinite Bus through a Pair of identical Transmission Lines Under 3-Phase Fault On One of the two Lines.
4	Y Bus Formation for Power Systems with and without Mutual Coupling, by Singular Transformation and Inspection Method.
5	Formation of Z Bus(without mutual coupling) using Z-Bus Building Algorithm.
6	Determination of Bus Currents, Bus Power and Line Flow for a Specified System Voltage (Bus) Profile.
7	Formation of Jacobian for a System not Exceeding 4 Buses (No PV Buses) in Polar Coordinates.
8	Load Flow Analysis using Gauss Siedel Method, NR Method and Fast Decoupled Method for Both PQ and PV Buses.
9	To Determine Fault Currents and Voltages in a Single Transmission Line System with Star-Delta Transformers at a Specified Location for LG and LLG faults by simulation.
10	Optimal Generation Scheduling for Thermal power plants by simulation.

Revised Bloom's Taxonomy Level:
L1 – Remembering, L2 – Understanding, L3 – Applying, L4 – Analysing, L5 – Evaluating, L6 – Creating.

Course outcomes:

At the end of the course the student will be able to:

- Develop a program in MATLAB to assess the performance of medium and long transmission lines.
- Develop a program in MATLAB to obtain the power angle characteristics of salient and non-salient pole alternator and assess the transient stability under three phase fault conditions.
- Develop programs in MATLAB to formulate bus admittance and bus impedance matrices of interconnected power systems.
- Use Mi-Power package to solve power flow problem for simple power systems.
- Use Mi-Power package to study unsymmetrical faults at different locations in radial power systems and optimal generation scheduling problems for thermal power plants.

CO – PO Mapping:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	2			3				1	2		
CO2	3	2			3				1	2		
CO3	3	2			3				1	2		
CO4	3	2			3				1	2		
CO5	3	2			3				1	2		

3- Strongly Related 2- Moderately Related 1-Weakly Related

CONTENTS

Expt.No-1(i)
Ybus formation by Inspection method.

Aim: Bus admittance matrix (Ybus) formation for power systems using inspection method.

Apparatus required: PC loaded with MATLAB

Theory: Bus admittance matrix or Ybus is matrix which gives the information about the admittances of lines connected to the node as well as the admittance between the nodes. Principal diagonal elements are called self admittances of node and is equal to the algebraic sum of all the admittances terminating at the node. Off diagonal elements are called mutual admittances and are equal to the admittances between the nodes. The size of ybus is n*n. Where n is the number of buses in the system and m= n+1(the total number of buses including the reference buses).

$I_{bus} = Y_{bus} * V_{bus}$ where I_{bus} = vector of impressed bus currents
Y_{bus} = bus admittance matrix.
V_{bus} = vector of bus voltages measured with respect to reference bus.

Inspection method makes use of KVL at all the nodes to get the current equations. From these equations, Ybus can be directly written. It is the simplest and direct method of obtaining all the diagonal elements as well as off diagonal elements in the matrix of any power system. Bus admittance matrix is a sparse matrix. It is often used in solving load flow problems. Sparsity is one of its greatest advantages as it heavily reduces computer memory and time requirements.

MATLAB Program:

```
clc
clear all
n=input('enter no. of buses:');                          % no. of buses excluding reference
nl= input('enter no. of lines:');                        % no. of transmission lines
sb= input('enter starting bus of each line:');           % starting bus of a line
eb= input('enter ending bus of each line');              % ending bus of a line
zser= input('enter resistance and reactance of each line:'); % line resistance and reactance (R, X)
yshty=     input('enter shunt admittance of the bus:');  % shunt admittance
i=0
k=1
while i<nl
      zser1(i+1)=zser(k)+j*zser(k+1)                     % impedance of a line (R+jX)
      i=i+1
      k=k+2
  end
zser2=reshape(zser1,nl,1);
yser=ones(nl,1)./zser2;
ybus=zeros(n,n);
for i=1:nl
```

```
    ybus(sb(i),sb(i))=ybus(sb(i),sb(i))+(j*yshty(i))+yser(i);
    ybus(eb(i),eb(i))=ybus(eb(i),eb(i))+(j*yshty(i))+yser(i);
    ybus(sb(i),eb(i))=-yser(i);
    ybus(eb(i),sb(i))=-yser(i);
  end
```

Input:

```
n=5
nl=7
sb=[1 1 2 2 2 3 4]
eb=[2 3 3 4 5 4 5]
zser=[0.02 0.06 0.08 0.24 0.06 0.18 0.06 0.18 0.04 0.12 0.01 0.03 0.08 0.24]
yshty=[0.03 0.025 0.02 0.02 0.015 0.01 0.025]
```

Output:

```
bus admittance matrix ybus
  6.25+(-18.70)j -5.00+( 15.00)j -1.25+(  3.75)j  0.00+(  0.00)j  0.00+(  0.00)j
 -5.00+( 15.00)j 10.83+(-32.42)j -1.67+(  5.00)j -1.67+(  5.00)j -2.50+(  7.50)j
 -1.25+(  3.75)j -1.67+(  5.00)j 12.92+(-38.70)j-10.00+( 30.00)j  0.00+(  0.00)j
  0.00+(  0.00)j -1.67+(  5.00)j-10.00+( 30.00)j 12.92+(-38.70)j -1.25+(  3.75)j
  0.00+(  0.00)j -2.50+(  7.50)j  0.00+(  0.00)j -1.25+(  3.75)j  3.75+(-11.21)j
```

Result:

Expt.No-1(ii)
Ybus formation by singular transformation method without Mutual coupling.

Aim: Bus admittance matrix (Y Bus) formation for power systems without mutual coupling using singular transformation method.

Apparatus required: PC loaded with MATLAB

Theory:

The **Y Matrix** is designated by *Ybus* and called *the bus admittance matrix*. Y matrix is a symmetric and square matrix that completely describes the configuration of power transmission lines. In realistic systems which are quite large containing thousands of buses, the Y matrix is quite sparse. Each bus in a real power system is usually connected to only a few other buses through the transmission lines. The **Y Matrix** is designated by *Ybus* and called *the bus admittance matrix*. Y matrix is a symmetric and square matrix that completely describes the configuration of power transmission lines. In realistic systems which are quite large containing thousands of buses, the Y matrix is quite sparse. Each bus in a real power system is usually connected to only a few other buses through the transmission lines.Ybus can be alternatively assembled by use of singular transformation given by a graph theoretical approach. This alternative approach is of great theoretical and practical significance.

Steps involving singular transformation:

1. Obtain the oriented graph for the given system.
2. Get the bus incidence matrix which is the one which indicates the incidence of all the elements to nodes in connected graph. The size of this matrix is e*(n-1) where e is the number of elements in the graph and n is the number of nodes (A)
3. Get the primitive admittance matrix from the graph of size e*e. If mutual coupling between the lines is neglected then the resulting primitive matrix is a diagonal matrix(off diagonal elements are zero)([y])
4. Ybus can be obtained from the equation, $Y_{bus} = A^t * [y] * A$

MATLAB Program:

```
clc
clear all
n=input('enter no. of buses:');                          % no. of buses excluding reference
nl= input('enter no. of lines:');                        % no. of transmission lines
sb= input('enter starting bus of each line:');           % starting bus of a line
eb= input('enter ending bus of each line');              % ending bus of a line
zser= input('enter resistance and reactance of each line:'); % line resistance and reactance (R, X)
yshty= input('enter shunt admittance of the bus:');      % shunt admittance
i=0;
k=1;
while i<nl
    zser1(i+1)=zser(k)+j*zser(k+1);                      % impedance of a line (R+jX)
```

```
      i=i+1;
      k=k+2;
  end
zser2=reshape(zser1,nl,1);
yser=ones(nl,1)./zser2;
ypri=zeros(nl+n,nl+n);
ybus=zeros(n,n);
a=zeros(nl+n,n);
for i=1:n
    a(i,i)=1;
end
for i=1:nl
    a(n+i,sb(i))=1;
    a(n+i,eb(i))=-1;
    ypri(n+i,n+i)=yser(i);
    ypri(sb(i),sb(i))=ypri(sb(i),sb(i))+yshty(i);
    ypri(eb(i),eb(i))=ypri(sb(i),eb(i))+yshty(i);
end
at=transpose(a);
ybus=at*ypri*a;
zbus=inv(ybus);
```

Input:

```
n= 3
nl=3
sb=[1 1 2 ]
eb=[2 3 3 ]
zser=[0.01 0.03 0.08 0.24 0.06 0.18 ]
yshty=[0.01 0.025 0.02]
```

Output:

```
bus admittance matrix
ybus:
 11.29 + (-33.75)j     -10.00 + ( 30.00)j     -1.25 + (  3.75)j
-10.00 + ( 30.00)j      11.70 + (-35.00)j     -1.67 + (  5.00)j
 -1.25 + (  3.75)j      -1.67 + (  5.00)j      2.94 + ( -8.75)j
```

Result:

Expt.No-1(iii)
Ybus formation by singular transformation method with Mutual coupling

Aim: Bus admittance matrix (Ybus) formation for power systems with mutual coupling using singular transformation method.

Apparatus required: PC loaded with MATLAB

Theory: The current flows through the coil and produces the flux in the same coil and this flux also links with the neighboring coil. The amount of the flux linking with the second coil is called mutual coupling. Then we say the two coils are mutually coupled. The amount of the energy spent in mutual coupling is measured by an impedance called mutual impedance. Hence the matlab program (Ybus formation using singular transformation without mutual coupling) should be modified by considering mutual coupling.

MATLAB program:

```
clc
clear all
n=input('enter no. of buses:');                          % no. of buses excluding reference
nl= input('enter no. of lines:');                        % no. of transmission lines
sb= input('enter starting bus of each line:');           % starting bus of a line
eb= input('enter ending bus of each line');              % ending bus of a line
zser= input('enter resistance and reactance of each line:');  % line resistance and reactance (R, X)
nmc= input('enter no. of mutual couplings:');
f1= input('enter first line no. of each mutual coupling:');
s1= input('enter second line no. of each mutual coupling:');
mz= input('enter mutual impedance between lines:');
i=0
k=1
while i<nl
      zser1(i+1)=zser(k)+j*zser(k+1)                     % impedance of a line (R+jX)

      i=i+1
      k=k+2
 end
i=0
k=1
while i<nmc
      mz1(i+1)=mz(k)+j*mz(k+1)
      i=i+1
      k=k+2
  end
zser2=reshape(zser1,nl,1);
mz2=reshape(mz1,2,1);
zpri=zeros(nl,nl);
a=zeros(nl,n)
```

```
for i=1:nl
    zpri(i,i)=zser2(i);
    if sb(i)~=0
        a(i,sb(i))=1;
    end
    if eb(i)~=0
        a(i,eb(i))=-1
    end
end
for i=1:nmc
   zpri(f1(i),s1(i))=mz2(i);
    zpri(s1(i),f1(i))=mz2(i);
end
 ypri=inv(zpri)
at=transpose(a)
ybus=at*ypri*a
zbus=inv(ybus)
```

Input:

```
n=3
nl=5
sb=[0 0 2 0 1]
eb=[1 2 3 1 3]
zser=[0 0.6 0 0.5 0 0.5 0 0.4 0 0.2]
nmc=2
f1=[1 1]
s1=[2 4]
mz=[0 0.1 0 0.2 ]
```

Output:

Bus admittance matrix is

```
  8.021 -0.208 -5.000
 -0.208  4.083 -2.000
 -5.000 -2.000  7.000
```

Bus impedance matrix is

```
  0.271  0.126  0.230
  0.126  0.344  0.189
  0.230  0.189  0.361
```

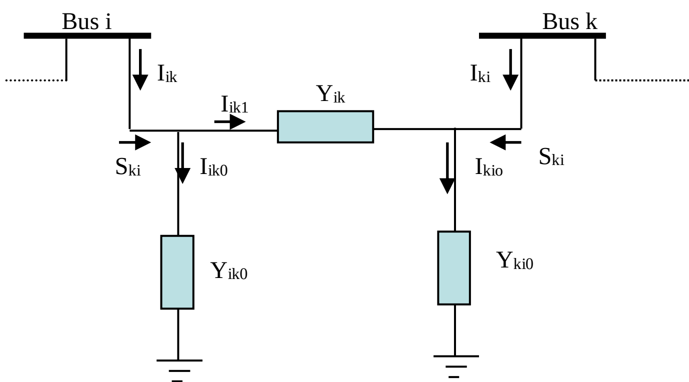
Result:

Expt.No-2
Determination of bus currents, bus power and line flows for a specified Bus system profile.

Aim: To determine the bus currents, bus power and line flows for any power system

Apparatus required: PC loaded with MATLAB

Theory: The last step in the load flow analysis is computing the power flows, bus currents and bus power on the various lines of the network.Consider the line connecting buses i and k. The line and transformer at each end can be represented by a circuit with series admittance Y_{ik} and two shunt admittances Y_{iko} and Y_{kio} as shown below.



The current fed by bus I into the line can be expressed as,
$I_{ik} = I_{ik1} + I_{iko} = (V_i – V_k)Y_{ik} + V_i\ Y_{ik0}$
The power fed into the line from bus i is
$S_{ik} = P_{ik} + jQ_{ik} = V_iI_{ik}^* = V_i(V_i^* - V_k^*)\ Y_{ik}^* + V_iV_i^*Y_{iko}^*$
The power fed into the line from bus k is
$S_{ki} = P_{ki} + jQ_{ki} = V_KI_{ki}^* = V_k(V_k^* - Vi^*)\ Y_{ik}^* + V_kV_k^*Y_{kio}^*$

The power loss in the (i-k) the line is the sum of the power flows determined from the last two equations. The transmission loss can be computed by summing all line flows (i.e $S_{ik} + S_{ki}$ for all i, k). The slack bus power can also be found by summing the flows on the lines terminating at the slack bus.

MATLAB program

```
clc
clear all
vbus=[1.05+0j;         .98-0.06j;         1-0.05j];                  % bus volatges
yline= [0 0 10 -20 10 -30 10 -20 0 0 16 -32 10 -30 16 -32 0 0 ];     % line G, B
n= 3                                                                  % no. of buses
i=0;
k=1;
while i<9
    yline1(i+1)=yline(k)+j*yline(k+1);
    i=i+1
    k=k+2
```

```
   end
yline2=reshape(yline1,3,3)                          % line admittance
Sp=zeros(n,n)
for i=1:n
   for k=1:n
      if i==k
         continue
      else
         I(i,k)=yline2(i,k)*(vbus(i)-vbus(k));      % line current
         I(k,i)= -I(i,k)
         S(i,k)=vbus(i)*conj(I(i,k));               % line power
         S(k,i)=vbus(k)*conj(I(k,i));
         Sl(i,k)=S(i,k)+S(k,i);                     % line losses
         Sp(i,i)=Sp(i,i)+S(i,k);                    % bus power
      end
   end
end
Sbus=[Sp(1,1); Sp(2,2); Sp(3,3)]
%bus curent calculation ;-
Ibus=conj((Sbus./vbus))                             % bus current
```

Input:

```
Yline= [0 0 10 -20 10 -30 10 -20 0 0 16 -32 10 -30 16 -32 0 0]
n= 3
```

Output:

```
line current matrix is
  0.00+(  0.00)j  1.90+( -0.80)j  2.00+( -1.00)j
 -1.90+(  0.80)j  0.00+(  0.00)j -0.64+(  0.48)j
 -2.00+(  1.00)j  0.64+( -0.48)j  0.00+(  0.00)j
line flow matrix is
  0.00+(  0.00)j  2.00+(  0.84)j  2.10+(  1.05)j
 -1.91+( -0.67)j  0.00+(  0.00)j -0.66+( -0.43)j
 -2.05+( -0.90)j  0.66+(  0.45)j  0.00+(  0.00)j
Line losses matrix is
  0.00+(  0.00)j  0.09+(  0.17)j  0.05+(  0.15)j
  0.09+(  0.17)j  0.00+(  0.00)j  0.01+(  0.02)j
  0.05+(  0.15)j  0.01+(  0.02)j  0.00+(  0.00)j
Bus power matrix is
  4.10+(  1.89)j  0.00+(  0.00)j  0.00+(  0.00)j
  0.00+(  0.00)j -2.57+( -1.10)j  0.00+(  0.00)j
  0.00+(  0.00)j  0.00+(  0.00)j -1.39+( -0.45)j
Sbus matrix is
  4.10+(  1.89)j -2.57+( -1.10)j -1.39+( -0.45)j
Ibus matrix is
  3.90+( -1.80)j -2.54+(  1.28)j -1.36+(  0.52)j
```

Result:

Expt.No-3
Calculation of ABCD parameters

Aim: To Calculate ABCD parameters for a given transmission line and find regulation and efficiency.

Apparatus required: PC loaded with MATLAB

Theory:

In any four terminal passive, linear and bilateral network, the input voltage and input current can be expressed in terms of output voltage and output current. Incidentally a transmission line is a 4 terminal network; input terminal where power enters the network and output terminal where power leaves the network. Therefore the input voltage (Vs) and input current (Is) of a 3- phase transmission line can be expressed as

Vs=A*Vr+B*Ir
Is=C*Vr+D*Ir

where, Vs= sending end voltage per phase
Is= sending end current
Vr= receiving end voltage per phase
Ir= receiving end current

A, B, C, D are known as generalized circuit constants of transmission line. The constants A and D are dimensionless as they are simply ratios whereas constants B and C are having unit's ohm and mho respectively. If the network is symmetrical then we have A = D. If the network is reciprocal then we have AD – BC = 1.

ABCD parameters for short transmission line:
A=1; B=Z; C=0; D=1.
Short transmission line: If the transmission line length is less than 80 km the line is treated as sort transmission line. As the line length is small the capacitive effects are small. Due to this effect of capacitance is neglected. Thus only resistance and inductance is to be taken into account while analyzing short transmission lines.

ABCD parameters for medium transmission line:
T network: A=D=1+YZ/2; B=Z(1+YZ/4); C=Y.
PI network: A=D=1+YZ/2; B=Z; C=Y(1+YZ/4).
Medium Transmission line: If the length of transmission line is lying between 80-240 km it is treated as medium transmission line. In the analysis of medium transmission line, the capacitance is taken into account as the line length is appreciable. For easiness in the calculations, the distributed capacitance of the line is divided and is lumped across the line at one or more points.

ABCD parameters for long transmission line:
$A=D=\cosh(YZ)^{1/2}$; $B=(Z/Y)^{1/2}*\sinh(YZ)^{1/2}$; $C=(Y/Z)^{1/2}*\sinh(YZ)^{1/2}$
Long Transmission line: if the length of transmission line is more than 240 km the line is considered as long transmission line. In the analysis of such lines, the line constants are considered uniformly distributed over the whole length of the line. The rigorous methods are applied to obtain the solution.

Calcuation of efficiency and regulation if sending end parameters are given:

```
clc
clear all
len=input('enter the length of the line in KM:');
r1=input('enter the resistance/phase/Km of the line:');
x1=input('enter the reactance/phase/Km of the line:');
s= input('enter the suspectance/phase/Km of the line:');
vs=input('enter the sending end voltage/ phase of the line:');
is=input('enter the  sending end current of the line:');
z=r1+j*x1;
y=j*s;
Z=z*len;
Y=y*len;
if len<=80
   x=1;
elseif len<=240
   x=2;
else
   x=3;
end
switch x
case 1
   A=1;
   B=Z;
   C=0;
   D=A;
case 2
   p=input('enter 1 for PI and 2 for T');
   A=1+(Y*Z)/2;
   D=A;
   if p==1
      B=Z;
      C=Y*(1+(Z*Y)/4);
   else
      C=Y;
      B=Z*(1+(Z*Y)/4);
   end
case 3
   A=cosh(sqrt(Y*Z));
   B=sqrt(Z/Y)*sinh(sqrt(Y*Z));
   C=sqrt(Y/Z)*sinh(sqrt(Y*Z));
   D=A;
end
ABCD=A*D-B*C;
vr=D*vs-B*is;
ir=-C*vs+A*is;
spower=3*vs*conj(is)
rpower=3*vr*conj(ir)
efficiency= real(rpower)/real(spower)*100;
```

regulation=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;

Input:
z=0.153+.38j;
y=0.0+.000003j;
vs=63508;
is=105-50.5j;

*** For short transmission line**
enter the length in KM 50

spower = 2.0005e+007 +9.6215e+006i
rpower = 1.9693e+007 +8.8477e+006i

abcd constants of transmission line are
A=1.000000+j0.000000
B=7.650000+j19.000000
C=0.000000+j0.000000
D=1.000000+j0.000000
sending end vs=63508.000000+j0.000000
sending end current=105.000000+j-50.500000
efficiency=98.442631
reg=2.819985
ad-bc=1.000000

*** For medium transmission line with pi network**
enter the length in KM200
enter 1 for PI and 2 for T 1

spower = 2.0005e+007 +9.6215e+006i
rpower = 1.8549e+007 +1.2389e+007i

abcd constants of transmission line are
A=0.977200+j0.009180
B=30.600000+j76.000000
C=-0.000003+j0.000593
D=0.977200+j0.009180
sending end vs=63508.000000+j0.000000
sending end current=105.000000+j-50.500000
efficiency=92.720923
reg=17.475816
ad-bc=1.000000

*** For medium transmission line with T network**
enter the length in KM 200
enter 1 for PI and 2 for T2

spower = 2.0005e+007 +9.6215e+006i
rpower = 1.8551e+007 +1.2505e+007i

abcd constants of transmission line are
A=0.977200+j0.009180
B=29.902320+j75.274054
C=0.000000+j0.000600
D=0.977200+j0.009180
sending end vs=63508.000000+j0.000000
sending end current=105.000000+j-50.500000
efficiency=92.731488
reg=17.253285
ad-bc=1.000000

<u>* For long transmission line</u>
enter the length in KM300

spower = 2.0005e+007 +9.6215e+006i
rpower = 1.7673e+007 +1.2772e+007i

abcd constants of transmission line are
A=0.949067+j0.020304
B=44.341614+j112.371757
C=-0.000006+j0.000885
D=0.949067+j0.020304
sending end vs=63508.000000+j0.000000
sending end current=105.000000+j-50.500000
efficiency=88.342221
reg=32.155708
ad-bc=1.000000

Calcuation of efficiency and regulation if receiving end parameters are given:

```
clc
clear all
len=input('enter the length in KM');
r1=input(‘enter the resistance/phase/Km of the line:’);
x1=input(‘enter the reactance/phase/Km of the line:’);
s= input(‘enter the suspectance/phase/Km of the line:’);
vr=input(‘enter the receiving end voltage/ phase of the line:’);
ir=input(‘enter the  receiving end current of the line:’);
z=r1+j*x1;
y=j*s;
Z=z*len;
Y=y*len;
if len<=80
   x=1;
elseif len<=240
   x=2;
else
   x=3;
end
```

```
switch x
case 1
   A=1;
   B=Z;
   C=0;
   D=A;
case 2
   p=input('enter 1 for PI and 2 for T');
   A=1+(Y*Z)/2;
   D=A;
   if p= =1
      B=Z;
      C=Y*(1+(Z*Y)/4);
   else
      C=Y;
      B=Z*(1+(Z*Y)/4);
   end
case 3
   A=cosh(sqrt(Y*Z));
   B=sqrt(Z/Y)*sinh(sqrt(Y*Z));
   C=sqrt(Y/Z)*sinh(sqrt(Y*Z));
   D=A;
end
ABCD=A*D-B*C;
vs=A*vr+B*ir;
is=C*vr+D*ir;
spower=3*vs*conj(is)
rpower=3*vr*conj(ir)
efficiency= real(rpower)/real(spower)*100;
regulation=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
```

Input:

```
z=0.153+.38j;
y=0.0+.000003j;
vr=63508;
ir=105-50.5j;
```

Short transmission line (50 km) given Vr and Ir

```
A=1.000000+j0.000000
B=7.650000+j19.000000
C=0.000000+j0.000000
D=1.000000+j0.000000
sending end vs=65270.750000+j1608.675000
sending end current=105.000000+j-50.500000
efficiency=98.466513
```

reg=2.806845
ad-bc=1.000000

Medium transmission line (200 km, PI) given Vr and Ir

A=0.977200+j0.009180
B=30.600000+j76.000000
C=-0.000003+j0.000593
D=0.977200+j0.009180
sending end vs=69111.017600+j7017.703440
sending end current=102.894689+j-10.714295
efficiency=94.775033
reg=11.929289
ad-bc=1.000000

Medium transmission line (200 km, T) given Vr and Ir

A=0.977200+j0.009180
B=29.902320+j75.274054
C=0.000000+j0.000600
D=0.977200+j0.009180
sending end vs=69001.100927+j6976.711950
sending end current=103.069590+j-10.279900
efficiency=94.718111
reg=11.746427
ad-bc=1.000000

Long transmission line given Vr and Ir

A=0.949067+j0.020304
B=44.341614+j112.371757
C=-0.000006+j0.000885
D=0.949067+j0.020304
sending end vs=70603.973689+j10849.218291
sending end current=100.287831+j10.388005
efficiency=92.700537
reg=18.487449
ad-bc=1.000000

Result:

Expt.No-4
Determination of power angle diagram for
a) Salient pole synchronous machine.
b) Non salient pole synchronous machine.

Aim: To determine the power angle diagram, reluctance power, excitation emf and regulation of salient pole and non-salient pole synchronous machine.

Apparatus required: PC loaded with MATLAB

Theory: The steady state stability is basically concerned with the determination of the maximum power flow possible through the power system, without loss of synchronism (stability). The formation of power angle equation plays a vital role in the study of steady state stability. The power angle equation for non salient pole machine is given by,

$$P = \frac{3|V||E|}{(X_d)} * \sin\delta$$

The above equation shows that the power P transmitted from the generator to the motor varies with the sine of the displacement angle δ between the two rotors.

For salient pole machine,

$$P = \frac{3|V||E|}{(X_d)} * \sin\delta + \frac{3|V|^2 * (X_d - X_q) * \sin(2\delta)}{2X_d X_q}$$

MATLAB PROGRAM:

```
clc
clear all
% power angle curve
p=input('power in MW = ');
pf=input('power factor = ');
vt=input('line voltage = ');
xd=input('xd in ohm = ');
xq=input('xq in ohm = ');
vt_ph=vt*1000/sqrt(3);
pf_a=acos(pf);
q=p*tan(pf_a);
i=(p-j*q)*1000000/(3*vt_ph);
delta=0:1:180;
delta_rad=delta*(pi/180);
if xd==xq
    % non salient syn motor
    ef=vt_ph+(j*i*xd);
    excitation_emf=abs(ef)
    reg=(abs(ef)-abs(vt_ph))*100/abs(vt_ph)
    power_non=abs (ef)*vt_ph*sin(delta_rad)/xd;
```

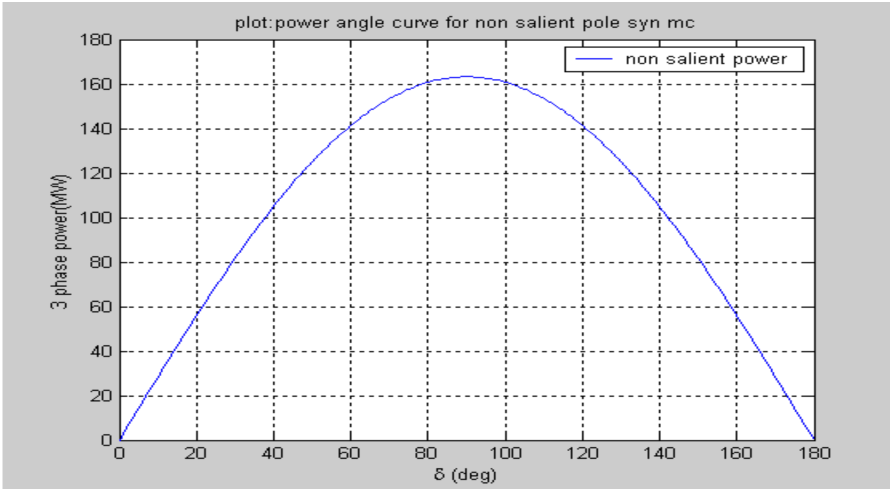
```
    net_power=3*power_non/1000000;
    plot(delta,net_power);
    xlabel('\delta (deg)');
    ylabel('3 phase power(MW)');
    title('plot:power angle curve for non salient pole syn mc');
    legend('non salient power')
end
if xd~=xq
    %salient pole motor
    eq=vt_ph+(j*i*xq);
    del=angle(eq);
    theta=del+pf_a;
    id_mag=abs(i)*sin(theta);
    ef_mag=vt_ph*cos(del)+id_mag*xd
    reg=(ef_mag-abs(vt_ph))*100/abs(vt_ph)
    pp=ef_mag*vt_ph*sin(delta_rad)/xd;
    reluct_power=vt_ph^2*(xd-xq)*sin(2*delta_rad)/(2*xd*xq);
    net_reluct_power=3*reluct_power/1000000;
    power_sal=pp+reluct_power;
    net_power_sal=3*power_sal/1000000;
    plot(delta,net_reluct_power);
    hold on
    plot(delta,net_power_sal);
    xlabel('\delta (deg)');
    ylabel('3 phase power(MW)');
    title('plot:power angle curve for salient pole syn mc');
    legend('reluct power','salient power')
end
grid;
```

Input data for salient pole synchronous machine:
power in MW = 48
power factor = .8
line voltage = 34.64
xd in ohm = 13.5
xq in ohm = 9.333

Result:
ef_mag = 3.0000e+004
reg = 50.0032

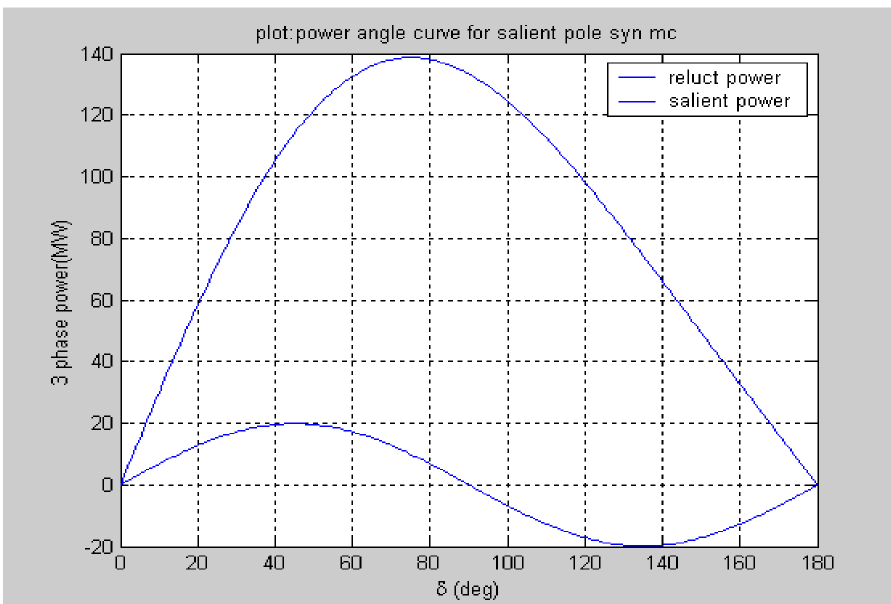
Input data for non salient pole synchronous machine:
power in MW = 48
power factor = .8
line voltage = 34.64
xd in ohm = 10
xq in ohm = 10

Result:
excitation_emf = 2.7203e+004
reg = 36.0171



graph-1

The above graph shows the power angle curve. The maximum power transfer occurs at delta=90^o. For values of delta >90^0 , the power output of the machine reduces successively and finally the machine may stall.The system is stable only if the displacement angle δ is in the range from -90^o to +90^o in which the slope dP/d δ is positive



graph-2

The graph-2 consists of a second harmonic component of power.
From the equation
P=V*E/Xd*sin(delta)+ V^{2*}(Xd-Xq)/2*Xd*Xq*sin(2*delta)
The first term is same as for non-salient pole machine with Xd=Xq. This constitutes the major part of the power transfer. The second term is quite small (10-20%) compared to the first term and known as reluctance power.

Expt.No-5
Determination of swing curve

Aim: To determine the Swing curve of a single machine connected to infinite bus

Apparatus required: PC loaded with MATLAB

Theory:

Transient stability limit : Transient stability limit of a two-machine system is defined as the maximum power that can be transmitted from one machine to the other without loss of synchronism for a specified, sudden, severe, unrepeated shock.

The load angle or the torque angle δ depends upon the loading of the machine, larger the loading larger is the value of the torque angle. If some load is added or removed from the shaft of the synchronous machine the rotor will decelerate or accelerate respectively with respect to rotating magnetic field. The rotor swings with respect to the stator field. The equation describing the relative motion of the rotor with respect to the stator field as a function of time is known as swing equation. The swing equation is given below

$$M\frac{d^2\delta}{dt^2} = P_s - P_e$$

Where Pe is Pm sin δ

M is the angular momentum of the rotor

δ is the torque angle

Ps is the power input

Pe is the electromagnetic power output

In case 'δ' increases indefinitely it indicates instability where as if it reaches a maximum and starts decreasing,it shows that the system will not lose stability since the oscillations will be damped out with time.

For the stability of the system $\frac{d\delta}{dt} = 0$

The system will be unstable if $\frac{d\delta}{dt} > 0$ for a sufficiently long time

Swing curve:

The solution of swing equation gives the relation between rotor angle 'δ' as a function of time 't' . The plot of 'δ' versus 't' is called as swing curve. No analytical solution of this equation exists. However, techniques are available to obtain approximate solution of such differential equations by numerical methods and one must therefore resort to numerical computation techniques. Some of the commonly used numerical techniques for the solution of the swing equation are:

- Point by point method
- Euler's method
- Euler's modified method
- Runge-Kutta method, etc.

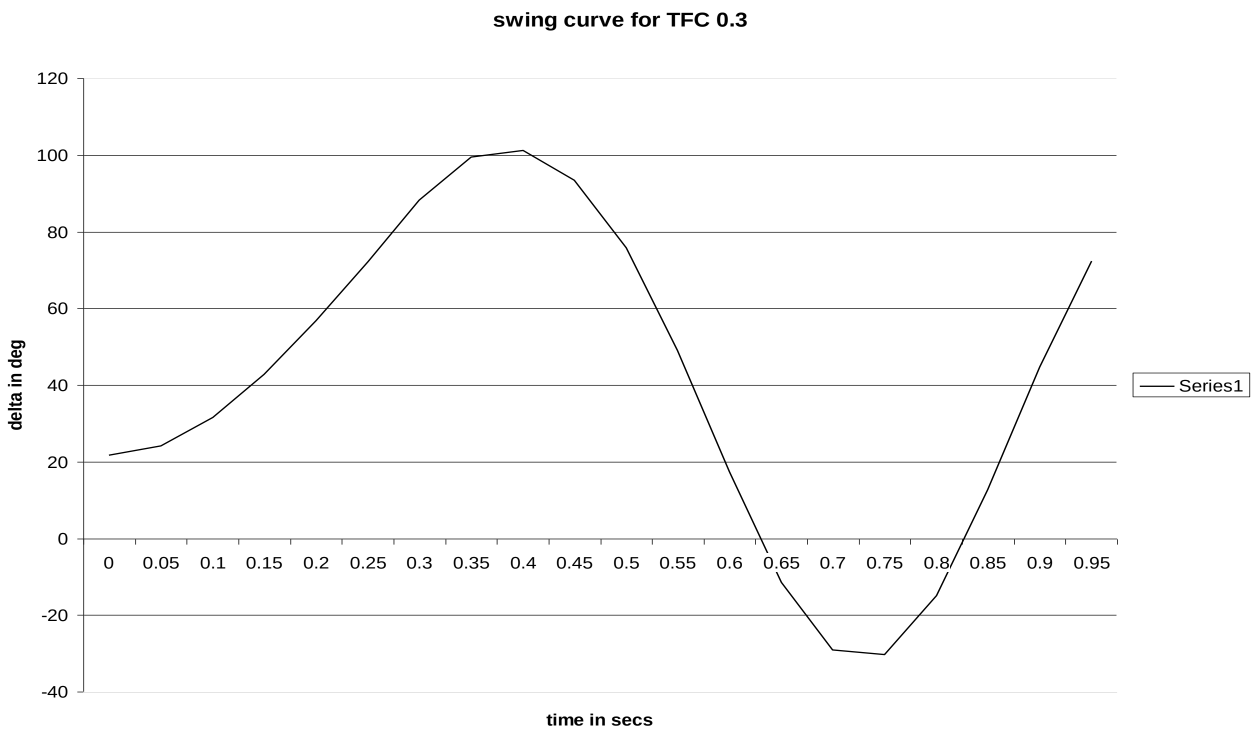
Note: In this program the swing equation is solved using Runge Kutta method

MATLAB PROGRAM:

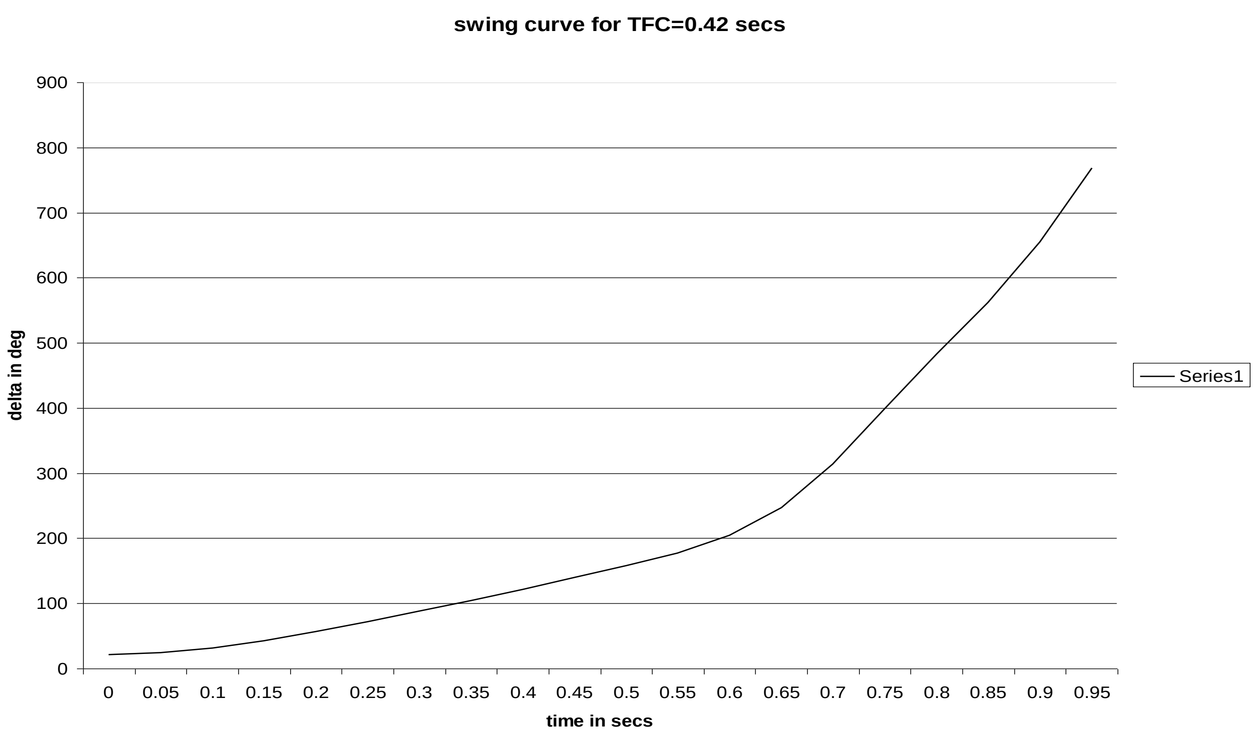
```
clc
clear all
tfc=input('enter fault clearing time=');
pi = 0.9;
e1=1.1;
e2=1.0;
m=0.016;
x0=0.45;
x1=1.25;
x2=0.55;
pm0=(e1*e2)/x0;
pm1=(e1*e2)/x1;
pm2=(e1*e2)/x2;
w=0;
d=asin(pi/pm0);
for t=0:0.05:1
   dg=d*180/3.1414;
   if(t<tfc)
   pm=pm1;
   else
   pm=pm2;
   end
   k1=w*.05;
   l1=(pi-pm*sin(d))*.05/m;
   k2=(w+.5*l1)*.05;
   l2=(pi-pm*sin(d+.5*k1))*.05/m;
   k3=(w+.5*l2)*.05;
   l3=(pi-pm*sin(d+.5*k2))*.05/m;
   k4=(w+l3)*.05;
   l4=(pi-pm*sin(d+k3))*.05/m;
   deld=(k1+2*k2+2*k3+k4)/6;
   delw=(l1+2*l2+2*l3+l4)/6;
   d=d+deld;
   w=w+delw;
   fprintf('%8.3f \t %8.3f  \n', t, dg);
end
```

Input data for swing curve:

Pi = 0.9;	e1=1.1;	e2=1.0
M=0.016		
X0=0.45 p.u;	X1=1.25 p.u;	X2=0.55 p.u



swing curve for TFC 0.3
delta in deg
time in secs
120
100
80
60
40
20
0
-20
-40
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
Series1



swing curve for TFC=0.42 secs
delta in deg
time in secs
900
800
700
600
500
400
300
200
100
0
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95
Series1

Result:

Expt.No-6
Jacobian Matrix Calculation

Aim: Formation of Jacobian for a system not exceeding 4 buses *(no PV buses) in polar coordinates

Apparatus required: PC loaded with MATLAB

Theory:

With the help of NR method, the above non – linear algebraic equations of power is transformed into a set of linear algebraic equations inter – relating the changes in power (that is error in power) with the change in real and reactive component of bus voltages with the help of jacobian matrix.

The Jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta \delta i^{(k)}$ and voltage magnitude $\Delta|Vi|^{(k)}$ with the small changes in real and reactive power $\Delta Pi^{(k)}$ and $\Delta Qi^{(k)}$. Elements of the jacobian matrix are the partial derivatives of

$$Pi = \sum_{J=1}^{n} |Vi|\,|Vj|\,|Yij| \cos(\theta ij - \delta i + \delta j)$$

$$Qi = -\sum_{J=1}^{n} |Vi|\,|Vj|\,|Yij| \sin(\theta ij - \delta i + \delta j)$$

Evaluated at $\Delta \delta i^{(k)}$ and $\Delta|Vi|^{(k)}$. In short it can be written as

MATLAB program:

```
clc
clear all
n=4
v=[1 1 1 1]
ybus=[70-90j -20+40j -50+50j 0+0j;-20+40j 43.08-55.39j 0+0j -23.077+15.39j;
    -50+50j 0+0j 75-75j -25+25j;0+0j -23.077+15.39j -25+25j 48.077-40.39j]
 for i=1:n
    for j=1:n
        y(i,j)=abs(ybus(i,j))
        yn(i,j)=angle(ybus(i,j))
        v(i)=abs(v(i))
        vn(i)=angle(v(i))
    end
 end
J1=zeros(n,n)
J2=zeros(n,n)
J3=zeros(n,n)
J4=zeros(n,n)
 i=2
 while i<=n
    J2(i,i)=J2(i,i)+2*v(i)*y(i,i)*cos(yn(i,i))
    J4(i,i)=J4(i,i)-2*v(i)*y(i,i)*sin(yn(i,i))
```

```
    for j=1:n
      if i==j
          continue;
       else
        J1(i,i)=J1(i,i)+v(i)*v(j)*y(i,j)*sin(yn(i,j)-vn(i)+vn(j))
        J1(i,j)=-1*v(i)*v(j)*y(i,j)*sin(yn(i,j)-vn(i)+vn(j))
        J2(i,i)=J2(i,i)+v(j)*y(i,j)*cos(yn(i,j)-vn(i)+vn(j))
        J2(i,j)=v(i)*y(i,j)*cos(yn(i,j)-vn(i)+vn(j))
        J3(i,i)=J3(i,i)+v(i)*v(j)*y(i,j)*cos(yn(i,j)-vn(i)+vn(j))
        J3(i,j)=-1*v(i)*v(j)*y(i,j)*cos(yn(i,j)-vn(i)+vn(j))
        J4(i,i)=J4(i,i)-v(j)*y(i,j)*sin(yn(i,j)-vn(i)+vn(j))
        J4(i,j)=-1*v(i)*y(i,j)*sin(yn(i,j)-vn(i)+vn(j))
    end
  end
  i=i+1
end
J11=J1(2:n,2:n)
J22=J2(2:n,2:n)
J33=J3(2:n,2:n)
J44=J4(2:n,2:n)
Jacobian=[J11 J22;J33 J44]
```

Output:

55.39	0.00	-15.39	43.08	0.00	-23.08
0.00	75.00	-25.00	0.00	75.00	-25.00
-15.39	-25.00	40.39	-23.08	-25.00	48.08
-43.08	0.00	23.08	55.39	0.00	-15.39
0.00	-75.00	25.00	0.00	75.00	-25.00
23.08	25.00	-48.08	-15.39	-25.00	40.39

Expt.No-7

MATLAB Program to Solve Load Flow Equations using Gauss-Seidel Method

AIM: To find load flow solution of the given power system using Gauss-Seidel method theoretically for one iteration and obtain full solution using MATLAB. (only PQ buses)

Theory:

Load flow analysis is the study conducted to determine the steady state operating condition of the given system under given conditions. A large number of numerical algorithms have been developed and Gauss Seidel method is one of such algorithm.

Problem Formulation

The performance equation of the power system may be written of

$$[I_{bus}] = [Y_{bus}][V_{bus}] \qquad (1)$$

Selecting one of the buses as the reference bus, we get (n-1) simultaneous equations. The bus loading equations can be written as

$$I_i = P_i - jQ_i / V_i^* \quad (i=1,2,3,\ldots\ldots n) \qquad (2)$$

Where,

$$P_i = \mathrm{Re}\left[\sum_{k=1}^{n} V_i^* Y_{ik} V_k\right]. \qquad (3)$$

$$Q_i = -\mathrm{Im}\left[\sum_{k=1}^{n} V_i^* Y_{ik} V_k\right]. \qquad (4)$$

The bus voltage can be written in form of

$$V_i = (1.0/Y_{ii})\left[I_i - \sum_{\substack{j=1 \\ j\neq i}}^{n} Y_{ij} V_j\right] \qquad (5)$$

$$(i=1,2,\ldots\ldots\ldots n) \;\&\; i\neq \text{slack bus}$$

Substituting Ii in the expression for Vi, we get

$$V_{i\,new} = (1.0/Y_{ii})\left[P_i - jQ_i / V_{io}^* - \sum_{J=1}^{n} Y_{ij} V_{io}\right] \qquad (6)$$

The latest available voltages are used in the above expression, we get

$$V_{i\,new} = (1.0/Y_{ii})\left[P_i - jQ_i / V^{o*}_{i} - \sum_{J=1}^{n} Y_{ij} V_j^{n} - \sum_{j=i+1}^{n} Y_{ij} V_{io}\right] \qquad (7)$$

The above equation is the required formula .this equation can be solved for voltages in interactive manner. During each iteration, we compute all the bus voltage and check for convergence is carried out by comparison with the voltages obtained at the end of previous iteration. After the solutions is obtained. The stack bus real and reactive powers, the reactive power generation at other generator buses and line flows can be calculated.

Algorithm:

Step1: Read the data such as line data, specified power, specified voltages, Q limits at the generator buses and tolerance for convergences

Step2: Compute Y-bus matrix.
Step3: Initialize all the bus voltages.

Step4: Iter=1

Step5: Consider i=2, where i' is the bus number.

Step6: check whether this is PV bus or PQ bus. If it is PQ bus goto step 8 otherwise go to next step.
Step7: Compute Qi check for q limit violation. QGi=Qi+QLi.

If QGi>Qi max ,equate QGi = Qimax. Then convert it into PQ bus.
If QGi<Qi min, equate QGi = Qi min. Then convert it into PQ bus.

Step8: Calculate the new value of the bus voltage using gauss seidal formula.

$$V_i=(1.0/Y_{ii})\left[(P_i-jQ_i)/v_i0^* - \sum_{J=1}^{i=1} Y_{ij}V_j - \sum_{J=i+1}^{n} Y_{ij}V_{j0}\right]$$

Adjust voltage magnitude of the bus to specify magnitude if Q limits are not violated.

Step9: If all buses are considered go to step 10 otherwise increments the bus no. i=i+1 and Go to step6.
Step10: Check for convergence. If there is no convergence goes to step 11 otherwise go to step12.
Step11: Update the bus voltage using the formula.

$Vi_{new}=Vi_{old}+\alpha(vi_{new}-Vi_{old})$ (i=1,2,…..n) i≠ slackbus ,α is the acceleration factor=1.4

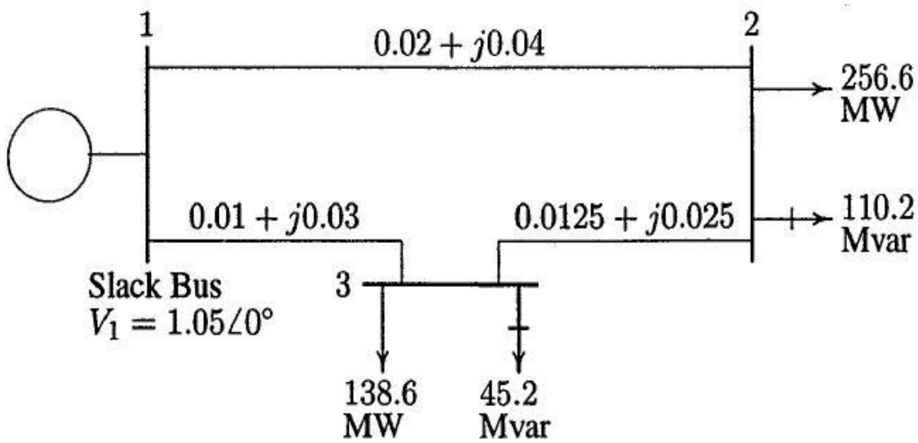
Step12: Calculate the slack bus power, Q at P-V buses real and reactive give flows real and reactance line losses and print all the results including all the bus voltages and all the bus angles.
Step13: Stop.

Procedure:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File.
3. Type and save the program in the editor Window.
4. Execute the program by pressing Tools – Run.
5. View the results.

PROBLEM:

a) The following figure shows the one-line diagram of a simple three-bus power system with generation at bus 1. The magnitude of voltage at bus 1 is adjusted to 1.05 per unit. The scheduled loads at buses 2 and 3 are as marked on the diagram. Line impedances are marked in per unit on a 100-MVA base and the line charging susceptances are neglected. Using the Gauss-Seidel method, determine the phasor values of the voltage at the load buses 2 and 3 (P-Q buses) accurate to four decimal places and obtain full solution using MATLAB.



MATLAB PROGRAM:

```
clc
clear all
n=3;
V=[1.05 1 1];
Y=[20-j*50     -10+j*20  -10+j*30
  -10+j*20    26-j*52      -16+j*32
  -10+j*30     -16+j*32   26-j*62]
P=[inf  -2.566  -1.386];
Q=[inf  -1.102  -0.452];
diff=10;
iter=1;
Vprev=V;
while (diff>0.00001 | iter==1),
abs(V);
abs(Vprev);
Vprev=V;
for i=2:n
sumyv=0;
for k=1:n,
if(i~=k)
sumyv=sumyv+Y(i,k)*V(k);
end
end
V(i)=(1/Y(i,i))*((P(i)-j*Q(i))/conj(V(i))-sumyv);
end
diff=max(abs(abs(V(2:n))-abs(Vprev(2:n))));
V
iter=iter+1
end
```

SOLUTION:

(a) Line impedances are converted to admittances

$$y_{12} = \frac{1}{0.02 + j0.04} = 10 - j20 \qquad y_{13} = 10 - j30$$

$$y_{23} = 16 - j32$$

```
YBUS =  [20-j*50    -10+j*20   -10+j*30
         -10+j*20   26-j*52    -16+j*32
         -10+j*30   -16+j*32    26-j*62]
```

At the P-Q buses, the complex loads expressed in per units are

$$S_2^{sch} = -\frac{(256.6 + j110.2)}{100} = -2.566 - j1.102 \quad \text{pu}$$

$$S_3^{sch} = -\frac{(138.6 + j45.2)}{100} = -1.386 - j0.452 \quad \text{pu}$$

Starting from an initial estimate of

$V_2^{(0)} = 1.0 + j0.0$ and $V_3^{(0)} = 1.0 + j0.0,$

$$V_2^{(1)} = \frac{\frac{P_2^{sch} - jQ_2^{sch}}{V_2^{*(0)}} + y_{12}V_1 + y_{23}V_3^{(0)}}{y_{12} + y_{23}}$$

$$= \frac{\frac{-2.566 + j1.102}{1.0 - j0} + (10 - j20)(1.05 + j0) + (16 - j32)(1.0 + j0)}{(26 - j52)}$$

$$= 0.9825 - j0.0310$$

$$V_3^{(1)} = \frac{\frac{P_3^{sch} - jQ_3^{sch}}{V_3^{*(0)}} + y_{13}V_1 + y_{23}V_2^{(1)}}{y_{13} + y_{23}}$$

$$= \frac{\frac{-1.386 + j0.452}{1 - j0} + (10 - j30)(1.05 + j0) + (16 - j32)(0.9825 - j0.0310)}{(26 - j62)}$$

$$= 1.0011 - j0.0353$$

The process is continued and a solution is converged with an accuracy of $1*10^{\wedge 5}$ per unit in six iterations as given below.

The final solution is

$$V_2 = 0.9800 - j0.0600 = 0.98183\angle{-3.5035^\circ} \quad \text{pu}$$
$$V_3 = 1.0000 - j0.0500 = 1.00125\angle{-2.8624^\circ} \quad \text{pu}$$

MATLAB OUTPUT:

Iter=1	V =	1.0500 + 0.0000i	0.9825 - 0.0310i	1.0011 - 0.0353i
Iter=2	V =	1.0500 + 0.0000i	0.9816 - 0.0520i	1.0008 - 0.0459i
iter =3	V =	1.0500 + 0.0000i	0.9808 - 0.0578i	1.0004 - 0.0488i
iter =4	V =	1.0500 + 0.0000i	0.9803 - 0.0594i	1.0002 - 0.0497i
iter =5	V =	1.0500 + 0.0000i	0.9801 - 0.0598i	1.0001 - 0.0499i
iter =6	V =	1.0500 + 0.0000i	0.9801 - 0.0599i	1.0000 - 0.0500i

Result:

Expt.No-8
Short circuit analysis for power system.

Aim: To determine fault currents and voltages in a single transmission line systems with star-delta transformers at a specified location for SLGF, DLGF.

Apparatus required: PC loaded with Mipower.

Theory:

Short circuit studies and hence the fault analysis are very important for the power system studies since they provide data such as voltages and currents during and after the various types of faults which are necessary in designing the protective schemes of the power system. There are different types of faults in a power system which can be broadly divided into symmetrical and unsymmetrical faults.
Symmetrical fault is the solid short circuit. This is an abnormal system behavior. Such conditions are caused in the system accidentally through insulation failure of equipment or flash over of lines initiated by a lightning stroke or through accidental faulty operation. The system must be protected against flow of heavy short circuit currents by disconnecting the faulty part of the system by means of circuit breaker operated by protective relaying.
The unsymmetrical faults require special tools like symmetrical components to analyze the unbalanced operation of the system. Though symmetrical faults are rare, this leads to most severe fault current flow against which the system must be protected.

Typical relative frequencies of occurrence of different kinds of faults in a power system in order of decreasing severity

Three phase fault	5%
Double line to ground fault (LLG)	10%
Double line fault (LL)	15%
Single line to ground fault (LG)	70%

Problem:

Data

Reactance of transmission lines = 0.3 p.u
Zero sequence reactance of transmission line = 0.25 p.u
Negative sequence reactance of generator = transient reactance of generator
Zero sequence reactance of generator = 0.1 p.u

Results of 3 phase fault

```
BUS DATA
NODE STAT ZONE BUS-KV   NAME     VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                              PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1  110.000     Bus1   1.0000    0.000    0.000    0.000
                                0.000    0.000    0.000
   2    1    1  110.000     Bus2   1.0000    0.000    0.000    0.000
                                0.000    0.000    0.000
```

```
  3    1    1  110.000     Bus3   1.0000    0.000    0.000    0.000
                                 0.000    0.000    0.000

--------------------------------------------------------------------------------
TRANSMISSION LINE DATA

STAT CKTS FROM FROM       TO TO
       NODE NAME     NODE NAME      RP(P.U)  XP(P.U) BP/2(PU)
                           RZ(P.U)  XZ(P.U) BZ/2(PU) FB-MVA TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
  3    1    1     Bus1    2     Bus2  0.00000  0.30000  0.00000
                           0.00000  0.75000  0.00000    110    110
  3    1    1     Bus1    3     Bus3  0.00000  0.30000  0.00000
                           0.00000  0.75000  0.00000    110    110
  3    1    2     Bus2    3     Bus3  0.00000  0.30000  0.00000
                           0.00000  0.75000  0.00000    110    110

--------------------------------------------------------------------------------
GENERATOR/MOTOR DATA

Classification Code :
0 : Generator
1 : Large Motor  >1000 hp for <= 1800 rpm, >250 hp for 3600 rpm
2 : Medium Motor >= 50 hp
3 : Small Motor  < 50 hp

FROM FROM          POSITIVE        NEGATIVE          ZERO                  CLASS
NODE NAME       R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA STAT CODE
---- -------- -------- -------- -------- -------- -------- -------- ------ ---- -----
   1     Bus1  0.00000  0.30000  0.00000  0.30000  0.00000  0.10000    110    3     0
   2     Bus2  0.00000  0.20000  0.00000  0.20000  0.00000  0.10000    110    3     0
   3     Bus3  0.00000  0.25000  0.00000  0.25000  0.00000  0.10000    110    3     0
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
FAULT AT BUS NUMBER     2 : NAME     Bus2
     CURRENT (AMPS/DEGREE)                    FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE       MAGNITUDE        MAGNITUDE
--------- -------  --------- -------        ---------        ---------
    4455  -90.00       4455  -90.00            849              849
       0  -90.00       4455  150.00              0              849
       0  -90.00       4455   30.00              0              849
R/X RATIO OF THE SHORT CIRCUIT PATH       :   0.0000
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :    12601 AMPS
PASCC = k x sqrt(2) x If , k =   2.0000
--------------------------------------------------------------------------------
POST FAULT BUS VOLTAGES
NUMBER NAME        SEQUENCE (1,2,0)       PHASE (A,B,C)
               MAGNITUDE   ANGLE     MAGNITUDE   ANGLE
------ --------    --------- -------     --------- -------
     1     Bus1        0.512    0.00                0.512    0.00
                       0.000  -90.00                0.512 -120.00
                       0.000  -90.00                0.512  120.00
     2     Bus2        0.000    0.00                0.000    0.00
                       0.000  -90.00                0.000 -120.00
                       0.000  -90.00                0.000  120.00
     3     Bus3        0.535   -0.00                0.535   -0.00
                   0.000  -90.00                    0.535 -120.00
```

```
                  0.000  -90.00                       0.535  120.00
-------------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM       TO TO            CURRENT (AMPS/DEGREE)       MVA
NODE NAME      NODE NAME       SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
               MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- --------  ---- --------  --------- ------- --------- ------- ---------
   2    Bus2    1    Bus1       895   90.00       895   90.00       171
                             0  -90.00      895  -30.00       171
                             0  -90.00      895 -150.00       171
   1    Bus1    3    Bus3        41   90.00        41   90.00         8
                             0  -90.00       41  -30.00         8
                             0  -90.00       41 -150.00         8
   2    Bus2    3    Bus3       936   90.00       936   90.00       178
                             0  -90.00      936  -30.00       178
                             0  -90.00      936 -150.00       178
-------------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM           CURRENT (AMPS/DEGREE)        MVA
NODE NAME      SEQUENCE (1,2,0)    PHASE (A,B,C)    PHASE(A,B,C)
          MAGNITUDE   ANGLE  MAGNITUDE   ANGLE  MAGNITUDE
---- --------  --------- -------  --------- -------  ---------
   1    Bus1       854   90.00       854   90.00       163
                 0  -90.00       854  -30.00       163
                 0  -90.00       854 -150.00       163
   2    Bus2      2624   90.00      2624   90.00       500
                 0  -90.00      2624  -30.00       500
                 0  -90.00      2624 -150.00       500
   3    Bus3       976   90.00       976   90.00       186
                 0  -90.00       976  -30.00       186
                 0  -90.00       976 -150.00       186
```

Results of LLG fault

```
BUS DATA
NODE STAT ZONE BUS-KV   NAME     VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                            PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1  110.000     Bus1   1.0000    0.000    0.000    0.000
                                    0.000    0.000    0.000
   2    1    1  110.000     Bus2   1.0000    0.000    0.000    0.000
                                    0.000    0.000    0.000
   3    1    1  110.000     Bus3   1.0000    0.000    0.000    0.000
                                    0.000    0.000    0.000

-------------------------------------------------------------------------------
TRANSMISSION LINE DATA

STAT CKTS FROM FROM       TO TO
       NODE NAME     NODE NAME     RP(P.U)  XP(P.U) BP/2(PU)
                     RZ(P.U)  XZ(P.U) BZ/2(PU) FB-MVA TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
   3    1    1     Bus1    2     Bus2  0.00000  0.30000  0.00000
                     0.00000  0.75000  0.00000     110     110
   3    1    1     Bus1    3     Bus3  0.00000  0.30000  0.00000
                     0.00000  0.75000  0.00000     110     110
   3    1    2     Bus2    3     Bus3  0.00000  0.30000  0.00000
                     0.00000  0.75000  0.00000     110     110
```

```
-------------------------------------------------------------------------------
GENERATOR/MOTOR DATA

Classification Code :
0 : Generator
1 : Large Motor  >1000 hp for <= 1800 rpm, >250 hp for 3600 rpm
2 : Medium Motor >= 50 hp
3 : Small Motor  < 50 hp

FROM FROM         POSITIVE        NEGATIVE          ZERO                 CLASS
NODE NAME      R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA STAT CODE
---- -------- -------- -------- -------- -------- -------- -------- ------ ---- -----
   1     Bus1  0.00000  0.30000  0.00000  0.30000  0.00000  0.10000    110    3     0
   2     Bus2  0.00000  0.20000  0.00000  0.20000  0.00000  0.10000    110    3     0
   3     Bus3  0.00000  0.25000  0.00000  0.25000  0.00000  0.10000    110    3     0
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
FAULT AT BUS NUMBER     2 : NAME     Bus2
     CURRENT (AMPS/DEGREE)                        FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE       MAGNITUDE        MAGNITUDE
--------- -------  --------- -------       ---------        ---------
    3166  -90.00         0  -90.00             603               0
    1289   90.00      4776  143.89             246             910
    1876   90.00      4776   36.11             358             910
-------------------------------------------------------------------------------
POST FAULT BUS VOLTAGES
NUMBER NAME        SEQUENCE (1,2,0)      PHASE (A,B,C)
              MAGNITUDE   ANGLE     MAGNITUDE   ANGLE
------ --------    --------- -------     --------- -------
    1    Bus1        0.653   -0.00        0.828   -0.00
                     0.141   -0.00        0.573 -129.33
                     0.034    0.00        0.573  129.33
    2    Bus2        0.289   -0.00        0.868   -0.00
                     0.289   -0.00        0.000  -62.69
                     0.289    0.00        0.000   64.14
    3    Bus3        0.669   -0.00        0.838   -0.00
                     0.135   -0.00        0.592 -128.47
                     0.034    0.00        0.592  128.47
-------------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM       TO TO            CURRENT (AMPS/DEGREE)       MVA
NODE NAME      NODE NAME       SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
               MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- --------  ---- --------  --------- ------- --------- ------- ---------
   2     Bus2    1     Bus1       636   90.00       198   90.00        38
                                  259  -90.00       858  -25.35       163
                                  179  -90.00       858 -154.65       163
   1     Bus1    3     Bus3        29   90.00        17   90.00         3
                                   12  -90.00        36  -13.67         7
                                    0    0.00        36 -166.33         7
   2     Bus2    3     Bus3       665   90.00       215   90.00        41
                                  271  -90.00       893  -24.88       170
                                  179  -90.00       893 -155.12       170
-------------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM           CURRENT (AMPS/DEGREE)        MVA
NODE NAME       SEQUENCE (1,2,0)    PHASE (A,B,C)    PHASE(A,B,C)
```

```
          MAGNITUDE   ANGLE  MAGNITUDE   ANGLE  MAGNITUDE
---- --------  --------- -------  --------- -------  ---------
   1     Bus1        607   90.00        181   90.00        35
                247  -90.00       822  -25.86       157
                179  -90.00       822 -154.14       157
   2     Bus2      1865   90.00        414  -90.00        79
                760  -90.00      3075  -42.35       586
               1519  -90.00      3075 -137.65       586
   3     Bus3        694   90.00        233   90.00        44
                283  -90.00       929  -24.44       177
                179  -90.00       929 -155.56       177
--------------------------------------------------------------------------------
```

Result of SLG fault

```
BUS DATA
NODE STAT ZONE BUS-KV   NAME     VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                              PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1  110.000     Bus1   1.0000    0.000    0.000    0.000
                                 0.000    0.000    0.000
   2    1    1  110.000     Bus2   1.0000    0.000    0.000    0.000
                                 0.000    0.000    0.000
   3    1    1  110.000     Bus3   1.0000    0.000    0.000    0.000
                                 0.000    0.000    0.000

--------------------------------------------------------------------------------
TRANSMISSION LINE DATA

STAT CKTS FROM FROM       TO TO
       NODE NAME     NODE NAME      RP(P.U)  XP(P.U) BP/2(PU)
                             RZ(P.U)  XZ(P.U) BZ/2(PU) FB-MVA TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
   3    1    1     Bus1    2     Bus2  0.00000  0.30000  0.00000
                             0.00000  0.75000  0.00000    110    110
   3    1    1     Bus1    3     Bus3  0.00000  0.30000  0.00000
                             0.00000  0.75000  0.00000    110    110
   3    1    2     Bus2    3     Bus3  0.00000  0.30000  0.00000
                             0.00000  0.75000  0.00000    110    110

--------------------------------------------------------------------------------
GENERATOR/MOTOR DATA

Classification Code :
0 : Generator
1 : Large Motor  >1000 hp for <= 1800 rpm, >250 hp for 3600 rpm
2 : Medium Motor >= 50 hp
3 : Small Motor  < 50 hp

FROM FROM          POSITIVE        NEGATIVE          ZERO                  CLASS
NODE NAME       R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA STAT CODE
---- -------- -------- -------- -------- -------- -------- -------- ------ ---- -----
   1     Bus1  0.00000  0.30000  0.00000  0.30000  0.00000  0.10000     110    3     0
   2     Bus2  0.00000  0.20000  0.00000  0.20000  0.00000  0.10000     110    3     0
   3     Bus3  0.00000  0.25000  0.00000  0.25000  0.00000  0.10000     110    3     0
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
FAULT AT BUS NUMBER     2 : NAME     Bus2
```

```
   CURRENT (AMPS/DEGREE)                    FAULT MVA
 SEQUENCE (1,2,0)   PHASE (A,B,C)     SEQUENCE (1,2,0)   PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE       MAGNITUDE        MAGNITUDE
--------- -------  --------- -------       ---------        ---------
    1658  -90.00       4974  -90.00            316              948
    1658  -90.00          0    0.00            316                0
    1658  -90.00          0    0.00            316                0
-----------------------------------------------------------------------------
POST FAULT BUS VOLTAGES
NUMBER NAME        SEQUENCE (1,2,0)       PHASE (A,B,C)
             MAGNITUDE   ANGLE     MAGNITUDE   ANGLE
------ --------    --------- -------     --------- -------
    1     Bus1       0.818    0.00        0.970   -0.00
                 0.182    0.00        0.765 -133.88
                 0.030 -180.00        0.765  133.88
    2     Bus2       0.628    0.00        0.000  -16.32
                 0.372 -180.00        0.947 -113.89
                 0.256 -180.00        0.947  113.89
    3     Bus3       0.827   -0.00        0.624    0.00
                 0.173  180.00        0.937 -112.40
                 0.030    0.00        0.937  112.40
-----------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM       TO TO             CURRENT (AMPS/DEGREE)       MVA
NODE NAME      NODE NAME      SEQUENCE (1,2,0)  PHASE (A,B,C)   PHASE(A,B,C)
                     MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- --------  ---- --------  --------- ------- --------- ------- ---------
   2     Bus2    1     Bus1       333   90.00       824   90.00       157
                         333   90.00       175  -90.00        33
                         158   90.00       175  -90.00        33
   1     Bus1    3     Bus3        15   90.00        30   90.00         6
                          15   90.00        15  -90.00         3
                           0 -128.13        15  -90.00         3
   2     Bus2    3     Bus3       348   90.00       854   90.00       163
                         348   90.00       190  -90.00        36
                         158   90.00       190  -90.00        36
-----------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM          CURRENT (AMPS/DEGREE)        MVA
NODE NAME      SEQUENCE (1,2,0)   PHASE (A,B,C)    PHASE(A,B,C)
           MAGNITUDE   ANGLE  MAGNITUDE   ANGLE  MAGNITUDE
---- --------  --------- -------  --------- -------  ---------
   1     Bus1       318   90.00       794   90.00       151
               318   90.00       160  -90.00        30
               158   90.00       160  -90.00        30
   2     Bus2       977   90.00      3295   90.00       628
               977   90.00       366   90.00        70
              1342   90.00       366   90.00        70
   3     Bus3       363   90.00       885   90.00       169
               363   90.00       205  -90.00        39
               158   90.00       205  -90.00        39
```

Result:

Expt.No-9
Load flow analysis for a 3bus system using Newton Raphson Method/Gauss seidel method

Aim: Load flow analysis using Newton Raphson Method/Gauss seidel method.

Apparatus Required: P.C loaded with Mipower package.

Theory: Load flow solution is a solution of a network under steady state condition subjected to certain inequality constraints under which the system operates. These constraints can be in the form load nodal voltages, reactive power generation of the generators, the tap setting of the tap changing transformer under load conditions.

The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels (through transmission line). Load flow solution is essential for designing a new power system and for planning extension of the existing one for increased load demand. These analysis require the calculations numerous load flows under both normal and abnormal operating conditions. Load flow solution also gives the initial conditions of the systems in the transient behavior of the system is to be obtained.
Load flow solution for power network can be worked out both ways accordingly as it is operating under balanced and unbalanced conditions.
The following treatment will be for a system operating under balanced conditions. For such a system single phase representation is adequate. A load flow solution of the power system requires mainly the following steps.

1) formulation or network equation
2) Suitable mathematical technique for solution of the equation.
3) The load and hence the generation are continuously varying in a real power system. We will assume here that loads and hence generations are fixed at a particular value over a suitable period of time. Example (½ hr)

Bus classification

In a power system each bus or a node is associated with four quantities

a) real power
b) reactive power
c) bus voltage magnitude
d) phase angle of the voltage

In a load flow solution two out of four quantities are specified and remaining two are required to be obtained. Depending upon which quantities are specified buses are classified as

1) generator bus
2) slack bus
3) load bus

Generator bus (voltage controlled bus)

Any bus of the system at which voltage magnitude is kept constant is called voltage controlled bus. At each bus to which there is a generator connected, the megawatt generation can be controlled by adjusting the prime mover and the voltage magnitude can be controlled by adjusting the generator excitation. Therefore at each generator bus
we may properly specify Pgi and $|Vi|$. Thus at the bus I angle delta and Qgi are the unknown quantities. Therefore it is also called as PV Bus.

Load bus (PQ bus)
At each non generator bus called bus both Pgi and Qgi are zero and real power Pdi and reactive power Qdi are drawn from the system by the load. The two unknown quantities are voltage magnitude and voltage angle (V and δ)

Slack bus
The losses remain unknown until the load flow solution is complete. It is for this reason generally one of the generator buses is made to take the additional real and reactive power to supply transmission losses that is why this bus is known as slack bus or swing bus. At this bus the voltage magnitude V and phase angle δ are specified where as Pgi and Qgi are unknown. The voltage angle of the slack bus serves as a reference for the angles of all other bus voltages.

Techniques of solving load flow problems
The development of any method for the load flow studies on the digital computer requires the following main consideration

1) mathematical formulation of the load flow problem
2) application of numerical technique to solve these problems

The mathematical formulation of load flow problem is a system of non linear algebraic equations.

The non-linear algebraic equations can be solved by the solution techniques such as iterative methods

1) Gauss method
2) Gauss- Seidel method
3) Newton Raphson method

Gauss Seidel method
In this method the value of bus voltages calculated for any bus immediately replace the previous values in the next step while in case of gauss method the calculated bus voltage replace the earlier value only at the end of iteration. Due to this Gauss Siedel method converges faster than that of Gauss method. This method solves the power flow equation in rectangular co-ordinates until the differences in the bus voltages from one iteration another are sufficiently small.

Newton Raphson method
It's a powerful method of solving non-linear algebraic equation. It works faster and is sure to converge in most of the cases as compared to the GS method. It is indeed a practical method of load flow solution of large power networks. Its only drawback is the large requirement of computer memory. Convergence can be considerably speeded up by performing the first iteration through the GS method and using the values so obtained for starting the NR iterations.
This method solves the polar form of the power flow equations until δp and δq mismatches, at all buses fall within the tolerance.

Fast Decoupled NR method
When solving large scale power transmission systems strategy for improving computational efficiency and reducing computer storage requirements is the decoupled load flow method. Incorporation of approximations of the decoupled method into the jacobian matrix makes the elements of the sub matrices J12 and J21 zero.

Therefore the modified jacobian now consists of the sub matrices J11 and J22.However J11 and J22 are still interdependent. The complications in solving J11 and J12 can be overcome by introducing further simplifications which are justified by the physics of transmission line power flow. Such a method is called as fast de coupled method.

Problem 1:

Each line has a series impedance of 0.02+j0.08 pu. Total shunt admittance of j0.02 pu. The specified quantities of the line buses are tabulated below on 100MVA base.

BUS	Real load demand	Reactive Load demand	Real Power Gen Pg	Reactive Power Gen Qg	Voltage specification
1	2 pu	1 pu	Unspecified	Unspecified	1.04 ∟0 slack bus
2	0 pu	0	0.5	1	Unspecified
3	1.5 pu	0.6 pu	0	Qg3=? (0-1.5pu)	1.04(pv)

Output:

Base case:

BUS VOLTAGES AND POWERS

```
NODE FROM      V-MAG  ANGLE       MW     MVAR       MW     MVAR     MVAR
NO.  NAME       P.U. DEGREE      GEN     GEN     LOAD    LOAD    COMP
---- --------  ------ ------  -------- --------  -------- -------- --------
   1     BUS1  1.0400   0.00   303.155   20.934   200.000  100.000    0.000
   2     BUS2  1.0819  -1.38    50.000  100.001     0.000    0.000    0.000 #>
   3     BUS3  1.0400  -3.75     0.000   45.023   150.000   60.000    0.000
-----------------------------------------------------------------------------
NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ MARK) :    0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (# MARK) :    1
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (< MARK)  :    0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (> MARK)  :    1
-----------------------------------------------------------------------------
```

LINE FLOWS AND LINE LOSSES

```
SLNO CS FROM FROM       TO TO           FORWARD          LOSS         %
      NODE NAME     NODE NAME         MW     MVAR      MW     MVAR LOADING
---- -- ---- -------- ---- -------- -------- -------- -------- -------- -------
   1  1    1    BUS1    2    BUS2   19.157  -59.886   0.7073   0.5771    58.4$
   2  1    1    BUS1    3    BUS3   83.998  -19.180   1.3652   3.2978    82.8#
   3  1    2    BUS2    3    BUS3   68.451   39.538   1.0838   2.0832    73.1$
-----------------------------------------------------------------------------
```

RESULTS :
LINE 1 OPEN:

BUS VOLTAGES AND POWERS

```
NODE FROM      V-MAG  ANGLE       MW     MVAR       MW     MVAR     MVAR
NO.  NAME       P.U. DEGREE      GEN     GEN     LOAD    LOAD    COMP
---- --------  ------ ------  -------- --------  -------- -------- --------
   1     BUS1  1.0400   0.00   304.154   72.093   200.000  100.000    0.000
   2     BUS2  1.1249  -3.72    50.000  100.000     0.000    0.000    0.000 #>
   3     BUS3  1.0441  -4.68     0.000   -0.000   150.000   60.000    0.000  <
```

```
-----------------------------------------------------------------------------
SLNO CS FROM FROM      TO TO          FORWARD         LOSS       %
      NODE NAME    NODE NAME        MW    MVAR      MW    MVAR LOADING
---- -- ---- -------- ---- -------- -------- -------- -------- -------- -------
  1   1    BUS1   2    BUS2    LINE IS OPEN
  2  1   1    BUS1   3    BUS3  104.155  -27.907   2.1390   6.3843   103.7@
  3  1   2    BUS2   3    BUS3   50.000  100.000   2.0161   5.7088    99.4#
-----------------------------------------------------------------------------
```

Problem 2(5 bus system)

Bus Data:

BUS NO	BUS VOLTAGE		GENERATION		LOAD		TYPE OF BUS
	MAGNITUDE	PHASE ANGLE	REAL	REACTIVE	REAL	REACTIVE	
1	-	-	0.0	0.0	0.45	0.15	PQ
2	-	-	0.0	0.0	0.4	0.05	PQ
3	-	-	0.0	0.0	0.6	0.1	PQ
4	1.047	-	0.4	0.3	0.2	0.1	PV
5	1.06	00					SLACK

LINE PARAMATERS:

LINE NO	BUS P	CODE Q	LINE PARAMETERS		
			RPU	XPU	B2PU
1	5	4	0.02	0.06	0.03
2	5	1	0.08	0.24	0.025
3	4	1	0.06	0.18	0.02
4	4	2	0.06	0.18	0.02
5	4	3	0.04	0.12	0.015
6	1	2	0.01	0.03	0.01
7	2	3	0.08	0.24	0.025

RESULTS

BASE CASE

```
-----------------------------------------------------------------------------
BUS VOLTAGES AND POWERS
NODE FROM      V-MAG  ANGLE      MW     MVAR      MW     MVAR    MVAR
NO.  NAME      P.U. DEGREE      GEN     GEN     LOAD     LOAD    COMP
---- --------  ------ ------  -------- --------  -------- -------- --------
  1    BUS1  1.0243  -5.00     0.000    0.000    45.000   15.000    0.000
  2    BUS2  1.0237  -5.33     0.000    0.000    40.000    5.000    0.000
  3    BUS3  1.0181  -6.15     0.000    0.000    60.000   10.000    0.000
  4    BUS4  1.0476  -2.81    40.000   30.312    20.000   10.000    0.000
  5    BUS5  1.0600   0.00   129.579   -7.759     0.000    0.000    0.000 #<
-----------------------------------------------------------------------------
LINE FLOWS AND LINE LOSSES
SLNO CS FROM FROM      TO TO          FORWARD         LOSS       %
      NODE NAME    NODE NAME        MW    MVAR      MW    MVAR LOADING
---- -- ---- -------- ---- -------- -------- -------- -------- -------- -------
  1  1   4    BUS4   5    BUS5  -87.449   6.430   1.4109  -2.4306   84.2#
  2  1   5    BUS5   1    BUS1   40.719   1.102   1.1914  -1.8578   38.4^
  3  1   4    BUS4   1    BUS1   24.695   3.564   0.3516  -3.2387   24.7&
  4  1   4    BUS4   2    BUS2   27.938   2.974   0.4413  -2.9669   27.5^
  5  1   4    BUS4   3    BUS3   54.824   7.344   1.1250   0.1739   52.8$
```

```
  6 1   1    BUS1   2    BUS2   18.874   -5.231   0.0356  -1.9903    19.1&
  7 1   2    BUS2   3    BUS3    6.332   -2.294   0.0307  -5.1192     6.8&
-------------------------------------------------------------------------------
```

RESULTS
LINE 1-2 REMOVED

```
-------------------------------------------------------------------------------
NODE FROM       V-MAG  ANGLE       MW     MVAR       MW     MVAR     MVAR
NO.  NAME        P.U. DEGREE      GEN     GEN      LOAD     LOAD     COMP
---- --------  ------ ------  -------- --------  -------- -------- --------
  1     Bus1  1.0264  -4.01     0.000    0.000    45.000   15.000    0.000
  2     Bus2  1.0190  -6.89     0.000    0.000    40.000    5.000    0.000
  3     Bus3  1.0162  -6.84     0.000    0.000    60.000   10.000    0.000
  4     Bus4  1.0476  -3.07    40.000   34.706    20.000   10.000    0.000
  5     Bus5  1.0600   0.00   129.926   -8.978     0.000    0.000    0.000 #<
-------------------------------------------------------------------------------
```

LINE FLOWS AND LINE LOSSES

```
SLNO CS FROM FROM       TO TO           FORWARD          LOSS         %
      NODE NAME     NODE NAME         MW     MVAR      MW     MVAR LOADING
---- -- ---- -------- ---- -------- -------- -------- -------- -------- -------
  1 1   4    Bus4   5    Bus5  -94.908    9.349   1.6706  -1.6513    91.7#
  2 1   5    Bus5   1    Bus1   33.347    2.023   0.8084  -3.0176    31.5^
  3 1   4    Bus4   1    Bus1   12.585    6.023   0.1235  -3.9314    15.5&
  4 1   4    Bus4   2    Bus2   40.966    2.098   0.9276  -1.4890    39.2^
  5 1   4    Bus4   3    Bus3   61.364    7.235   1.4012   1.0084    59.0$
  6   1    Bus1   2    Bus2      LINE IS OPEN
  7 1   2    Bus2   3    Bus3    0.038   -1.408   0.0011  -5.1744     3.7&
-------------------------------------------------------------------------------
```

Result:

Expt.No-10
Optimal generator scheduling for thermal power plants

Aim: To determine the optimal generator scheduling for thermal power plants using Mipower package

Apparatus required: PC loaded with Mipower.

Theory: For a power plant the total cost of operation includes fuel, maintenance, and labor costs, but we will assume that changes in output are relatively small, so that fuel cost is the only important one.

If we let **P** stand for the power output in megawatts MW) and **C** be the fuel cost, then Fig. shows a typical curve of cost versus power output.

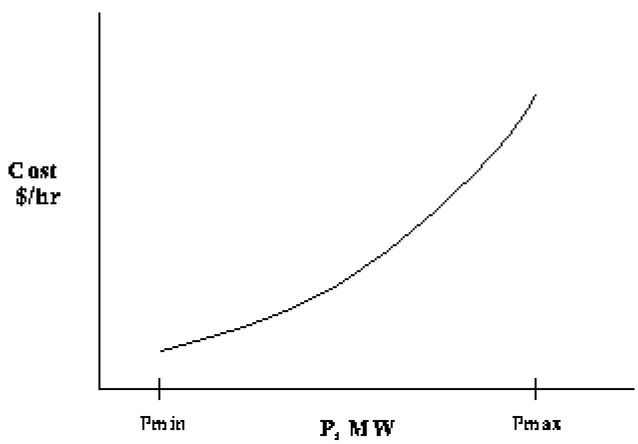


Figure: Typical Fuel-Cost curve for a single power plant

It is seen that the cost curve is increasing and concave upward. In practice, a quadratic polynomial is often used to fit fuel-cost data. There are minimum and maximum values of **P**, **Pmax** and **Pmin**, corresponding to feasible limits of operation of the plant. The need for an upper limit should be clear; a given plant can't produce more power than it is designed for. The lower limit usually comes from thermodynamic and/or practical considerations, *e.g.* the fuel burning rate has to be above a certain value or the flame goes out.

Problem:
Given the cost equation and loss co-efficient of different units in a plant.
Determination of economic generation using the available software package for given total load demand in MW with and without B co-efficient.

For 3 machine system:

Cost equations are:

$C1=0.05P1^2 + 20P1+800$ Rs./MWh $0<P1<150$
$C2=0.06P2^2 + 15P2+1000$ Rs./MWh $0<P1<150$
$C3=0.07P3^2 + 18P3+900$ Rs./MWh $0<P1<200$

$B_{11}=0.0005$ $B_{22}=0.0004$ $B_{33}=0.0005$

$B_{12}= B_{21}= 0.00005$ $B_{23}= B_{23}= 0.00018$
$B_{13}= B_{31}=0.0002\ MW^{-1}$

For 2 machine system:

Cost equations are:

$C1=0.015P1^2 + 16P1+50$ Rs./MWh $0<P1<150$
$C2=0.025P2^2 + 12P2+30$ Rs./MWh $0<P1<100$

$B_{11}=0.005$ $B_{22}=0.002$ $B_{33}=0.0005$
$B_{12}= B_{21}= 0.0012\ MW^{-1}$

Results:
Total Demand – 150MW, No of generators 2 (neglecting transmission loss)
Iter count 20   Lambda 17.500002   Total gen 150.000061
Total loss 0.000000
Total load 150.000000   Delta power 0.000061

Final Cost of generation at Generator 1 = 887.501134 Rs for 50.000065 MW
Final Cost of generation at Generator 2 = 1480.000004 Rs for 100.000000 MW

Final Total generation cost is Rs   2367.501221

Total Demand – 200MW, No of generators - 3 (by considering transmission losses)

Iter count 35   Lambda 29.060001   Total gen 210.748566
Total loss 10.786809
Total load 200.000000   Delta power -0.038243

Final Cost of generation at Generator 1 = 2261.151622 Rs for 63.102703 MW
Final Cost of generation at Generator 2 = 2830.295597 Rs for 89.778786 MW
Final Cost of generation at Generator 3 = 2176.009584 Rs for 57.867088 MW

Final Total generation cost is Rs   7267.457031

Result:

Expt.No-11

Z-BUS BUILDING ALGORITHEM

Aim: Formation of Z-bus, using Z-bus build Algorithm without mutual.

Theory: It is a step-by-step programmable technique which proceeds branch by branch. It has the advantage that any modification of the network does not require complete rebuilding of Z_{BUS} •

Consider that Z_{BUS} has been formulated upto a certain stage and another branch is now added. Then

$$Z_{BUS}\text{ (old)} \xrightarrow{Z_b = \text{branch impedance}} Z_{BUS}\text{ (new)}$$

Upon adding a new branch, one of the following situations is presented.

1. Z_b is added from a new bus to the reference bus (i.e. a new branch is added and the dimension of Z_{BUS}goes up by one). This is *type-I modification.*
2. Z_b is added from a new bus to an old bus (i.e., a new branch is added and the dimension of Z_{BUS} goes up by one). This is *type-2 modification.*
3. Z_b connects an old bus to the reference branch (i.e., a new loop is formed but the dimension of Z_{BUS} does not change). This is *type-3 modification.*
4. Z_b connects two old buses (i.e., new loop is formed but the dimension of Z_{BUS} does not change). This is *type-4 modification.*
5. Z_b connects two new buses (Z_{BUS} remains unaffected in this case). This situation can be avoided by suitable numbering of buses and from now onwards will be ignored.

Notation: *i, j—old* buses; r—reference bus; *k—new* bus.

Procedure:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File
3. Type and save the program in the editor window.
4. Execute the program by pressing Tools – Run.
5. View the results.

Expected Result:

Type = 1
Zbus =[0.2500]

Type = 2
Zbus = [0.2500 0.2500; 0.2500 0.3500]

Type = 2
Zbus =[0.2500 0.2500 0.2500;   0.2500 0.3500 0.2500;   0.2500 0.2500 0.3500]

Zbus =[0.1458 0.1042 0.1458;   0.1042 0.1458 0.1042;   0.1458 0.1042 0.2458]

Zbus = [0.1397 0.1103 0.1250;   0.1103 0.1397 0.1250;   0.1250 0.1250 0.1750]

PROGRAM:

```
%Zprim=[Element no.    from    to     Value]
clc
clear all
Z= [ 1 1 0 0.25
       2 2 1 0.1
       3 3 1 0.1
       4 2 0 0.25
       5 2 3 0.1];
 [m n]= size(Z);
Zbus=[ ] ;
%Let Zbus be a null matrix to begin with
 currentbusno=0;
for count = 1:m,
 [rows cols]=size(Zbus);
fb=Z(count,2);
tb=Z(count,3);
value=Z(count,4);
newbus=max(fb,tb);
ref=min(fb,tb);
% Type 1 Modification
if newbus > currentbusno & ref==0
Type=1
Zbus=[Zbus zeros(rows,1);
          zeros(1,cols) value]
currentbusno=newbus;
continue
end
% Type 2 Modification
if newbus > currentbusno & ref~=0
Type=2
Zbus=[Zbus   Zbus(:,ref);
          Zbus(ref,:)  value+Zbus(ref,ref)]
currentbusno=newbus;
 continue
 end
% Type 3 Modification
if newbus <= currentbusno & ref==0
Zbus=Zbus-1/(Zbus(newbus,newbus)+value)*Zbus(:,newbus)*Zbus(newbus,:)
continue
end
% Type 4 Modification
if newbus <= currentbusno & ref~=0
Zbus=Zbus-1/(value+Zbus(fb,fb)+Zbus(tb,tb)- 2*Zbus(fb,tb))*((Zbus(:,fb)-Zbus(:,tb))*((Zbus(fb,:)-
Zbus(tb,:))))
continue
end
end
```

A.1 SINUSOIDAL VOLTAGES AND CURRENTS

Aim: To determine sinusoidal voltages and currents

Apparatus: MATLAB

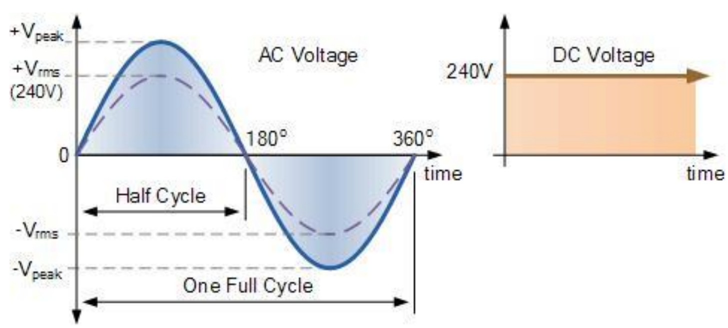
Theory : The RMS Voltage of an AC Waveform

The RMS value is the square root of the mean (average) value of the squared function of the instantaneous values. The symbols used for defining an RMS value are V_{RMS} or I_{RMS}.

The term RMS, refers to time-varying sinusoidal voltages, currents or complex waveforms were the magnitude of the waveform changes over time and is not used in DC circuit analysis or calculations were the magnitude is always constant. When used to compare the equivalent RMS voltage value of an alternating sinusoidal waveform that supplies the same electrical power to a given load as an equivalent DC circuit, the RMS value is called the "effective value" and is presented as: V_{eff}or I_{eff}.

In other words, the effective value is an equivalent DC value which tells you how many volts or amps of DC that a time-varying sinusoidal waveform is equal to in terms of its ability to produce the same power. For example, the domestic mains supply in the United Kingdom is 240Vac. This value is assumed to indicate an effective value of "240 Volts RMS". This means then that the sinusoidal RMS voltage from the wall sockets of a UK home is capable of producing the same average positive power as 240 volts of steady DC voltage as shown below.

RMS Voltage Equivalent



Circuit diagram:

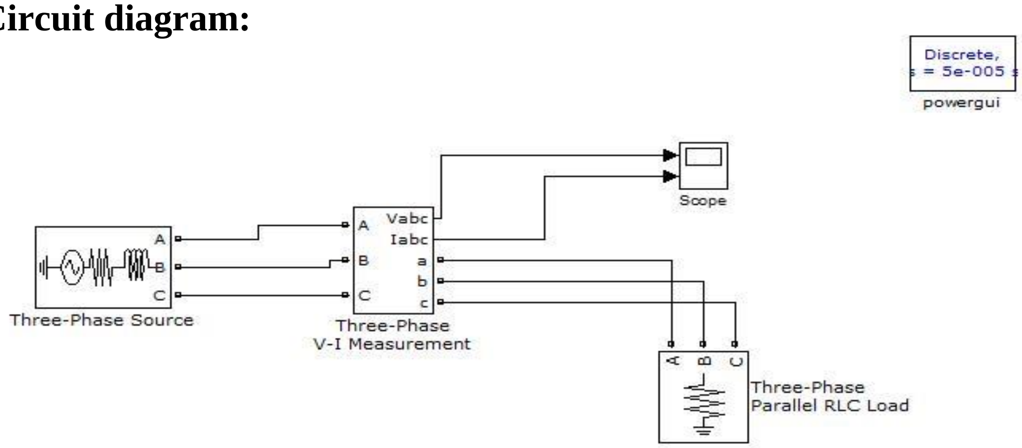
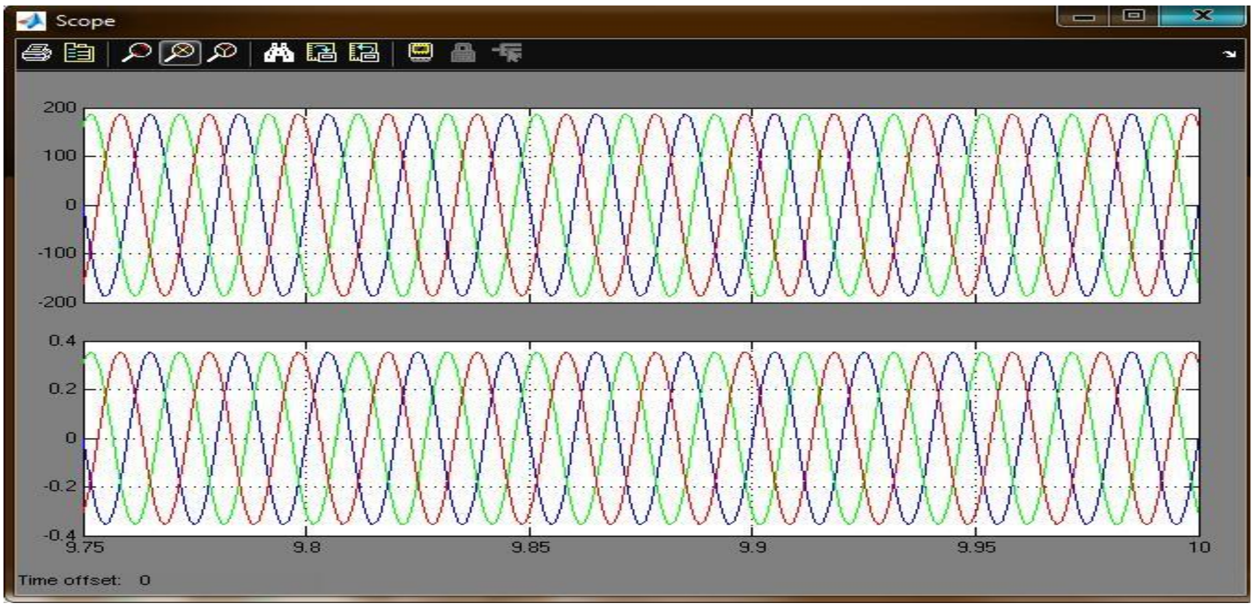


Fig: Simulink model for voltage and current measurement

Procedure:

1. Open Matlab-->Simulink--> File ---> New---> Model
2. Open Simulink Library and browse the components
3. Connect the components as per circuit diagram
4. Set the desired voltage and required frequency
5. Simulate the circuit using MATLAB
6. Plot the waveforms.

Graph:



Result:

A.2 UNSYMMETRICAL FAULT ANALYSIS

Aim: To analyse unsymmetrical fault

Apparatus: MATLAB

Theory:

Single Line-to-Ground Fault: The single line-to-ground fault is usually referred as "short circuit" fault and occurs when one conductor falls to ground or makes contact with the neutral wire. The general representation of a single line-to-ground fault is shown in Figure 3.10 where F is the fault point with impedances Z_f. Figure 3.11 shows the sequences network diagram. Phase a is usually assumed to be the faulted phase, this is for simplicity in the fault analysis calculations.

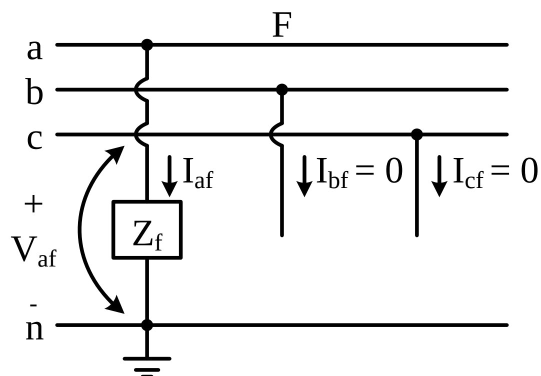


Figure 3.10 General representation of a single line-to-ground fault.

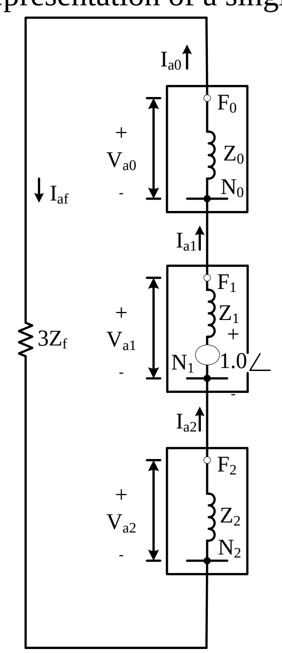


Figure 3.11 Sequence network diagram of a single line-to-ground fault.

Since the zero-, positive-, and negative-sequence currents are equals as it can be observed in Figure 3.11. Therefore,

$$I_{a0} = I_{a1} = I_{a2} = \frac{1.0\angle 0^\circ}{Z_0 + Z_1 + Z_2 + 3Z_f} \tag{3.48}$$

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \tag{3.49}$$

Solving Equation the fault current for phase a is

$$I_{af} = I_{a0} + I_{a1} + I_{a2} \tag{3.50}$$

it can also be

$$I_{af} = 3I_{a0} = 3I_{a1} = 3I_{a2} \tag{3.51}$$

From Figure 3.10 it can be observed that,

$$V_{af} = Z_f I_{af} \tag{3.52}$$

The voltage at faulted phase a can be obtained by substituting Equation 3.49 into Equation 3.52. Therefore,

$$V_{af} = 3Z_f I_{a1} \tag{3.53}$$

but, $$V_{af} = V_{a0} + V_{a1} + V_{a2} \tag{3.54}$$

therefore, $$V_{a0} + V_{a1} + V_{a2} = 3Z_f I_{a1} \tag{3.55}$$

With the results obtained for sequence currents, the sequence voltages can be obtained from

$$\begin{bmatrix} V_{a0} \\ V_{b1} \\ V_{c2} \end{bmatrix} = \begin{bmatrix} 0 \\ 1.0\angle 0^\circ \\ 0 \end{bmatrix} - \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \tag{3.56}$$

By solving Equation

$$\begin{aligned} V_{a0} &= -Z_0 I_{a0} \\ V_{a1} &= 1.0 - Z_1 I_{a1} \\ V_{a2} &= -Z_2 I_{a2} \end{aligned} \tag{3.57}$$

If the single line-to-ground fault occurs on phase b or c, the voltages can be found by the relation that exists to the known phase voltage components,

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \tag{3.58}$$

as

$$\begin{aligned} V_{bf} &= V_{a0} + a^2 V_{a1} + a V_{a2} \\ V_{cf} &= V_{a0} + a V_{a1} + a^2 V_{a2} \end{aligned} \tag{3.59}$$

Line-to-Line Fault: A line-to-line fault may take place either on an overhead and/or underground transmission system and occurs when two conductors are short-circuited. One of the characteristic of this type of fault is that its fault impedance magnitude could vary over a wide range making very hard to predict its upper and lower limits. It is when the fault impedance is zero that the highest asymmetry at the line-to-line fault occurs.

The general representation of a line-to-line fault is shown in Figure 3.12 where F is the fault point with impedances Z_f. Figure 3.13 shows the sequences network diagram. Phase b and c are usually assumed to be the faulted phases; this is for simplicity in the fault analysis calculations.

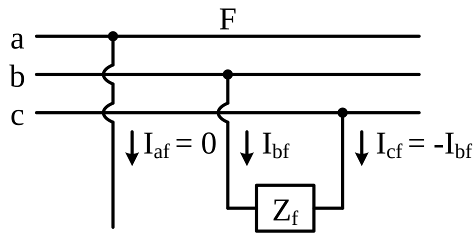


Figure 3.12 Sequence network diagram of a line-to-line fault.

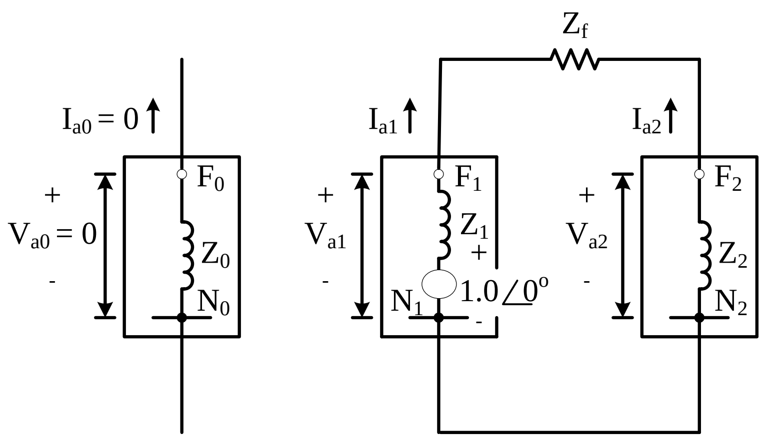


Figure 3.13 Sequence network diagram of a single line-to-ground fault.

From Figure 3.13 it can be noticed that

$$I_{af} = 0$$

$$I_{bf} = -I_{cf} \qquad (3.60)$$

$$V_{bc} = Z_f I_{bf}$$

And the sequence currents can be obtained as

$$I_{a0} = 0 \qquad (3.61)$$

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2 + Z_f} \qquad (3.62)$$

If $Z_f = 0$,

$$I_{a1} = -I_{a2} = \frac{1.0\angle 0^\circ}{Z_1 + Z_2} \qquad (3.63)$$

The fault currents for phase b and c can be obtained by substituting Equations 3.61 and 3.62 into Equation 3.49

$$I_{bf} = -I_{cf} = \sqrt{3}\, I_{a1}\angle -90^\circ \qquad (3.64)$$

The sequence voltages can be found similarly by substituting Equations 3.61 and 3,62 into Equation 3.56

$$V_{a0} = 0$$
$$V_{a1} = 1.0 - Z_1 I_{a1} \quad (3.65)$$
$$V_{a2} = -Z_2 I_{a2} = Z_2 I_{a1}$$

Also substituting Equation 3.65 into Equation 3.58

$$V_{af} = V_{a1} + V_{a2} = 1.0 + I_{a1}(Z_2 - Z_1)$$
$$V_{bf} = a^2 V_{a1} + aV_{a2} = a^2 + I_{a1}(aZ_2 - a^2 Z_1)$$
$$V_{cf} = aV_{a1} + a^2 V_{a2} = a + I_{a1}(a^2 Z_2 - aZ_1) \quad (3.66)$$

Finally, the line-to-line voltages for a line-to-line fault can be expressed as

$$V_{ab} = V_{af} - V_{bf}$$
$$V_{bc} = V_{bf} - V_{cf}$$
$$V_{ca} = V_{cf} - V_{af} \quad (3.67)$$

Double Line-to-Ground Fault: A double line-to-ground fault represents a serious event that causes a significant asymmetry in a three-phase symmetrical system and it may spread into a three-phase fault when not clear in appropriate time. The major problem when analyzing this type of fault is the assumption of the fault impedance Z_f, and the value of the impedance towards the ground Z_g..

The general representation of a double line-to-ground fault is shown in Figure 3.14 where F is the fault point with impedances Z_f and the impedance from line to ground Z_g . Figure 3.15 shows the sequences network diagram. Phase b and c are assumed to be the faulted phases, this is for simplicity in the fault analysis calculations.

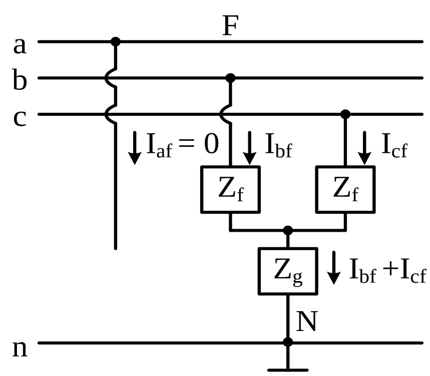


Figure 3.14 General representation of a double line-to-ground fault.

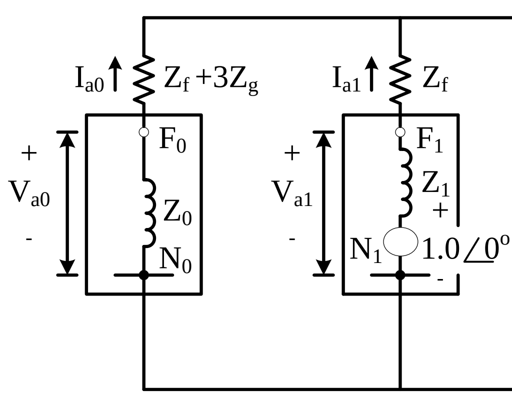


Figure 3.15 Sequence network diagram of a double line-to-ground fault.

From Figure 3.15 it can be observed that

$$I_{af} = 0$$

$$V_{bf} = (Z_f + Z_g)I_{bf} + Z_g I_{cf} \tag{3.68}$$

$$V_{cf} = (Z_f + Z_g)I_{cf} + Z_g I_{bf}$$

Based on Figure 3.15, the positive-sequence currents can be found as

$$I_{a1} = \frac{1.0\angle 0^\circ}{(Z_1 + Z_f) + \dfrac{(Z_2 + Z_f)(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}}$$

$$I_{a2} = -[\frac{(Z_0 + Z_f + 3Z_g)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}]I_{a1} \tag{3.69}$$

$$I_{a0} = -[\frac{(Z_2 + Z_f)}{(Z_2 + Z_f) + (Z_0 + Z_f + 3Z_g)}]I_{a1}$$

An alternative method is,

$$I_{af} = 0 = I_{a0} + I_{a1} + I_{a2}$$

$$I_{a0} = -(I_{a1} + I_{a2}) \tag{3.70}$$

If Z_f and Z_g are both equal to zero, then the positive-, negative-, and zero-sequences can be obtained from

$$I_{a1} = \frac{1.0\angle 0^\circ}{(Z_1) + \dfrac{(Z_2)(Z_0)}{(Z_2 + Z_0)}}$$

$$I_{a2} = -[\frac{(Z_0)}{(Z_2 + Z_0)}]I_{a1} \tag{3.71}$$

$$I_{a0} = -[\frac{(Z_2)}{(Z_2 + Z_0)}]I_{a1}$$

From Figure 3.14 the current for phase a is

$$I_{af} = 0 \tag{3.72}$$

Now, substituting Equations 3.71 into Equation 3.49 to obtain phase b and c fault currents

$$I_{bf} = I_{a0} + a^2 I_{a1} + aI_{a2}$$

$$I_{cf} = I_{a0} + aI_{a1} + a^2 I_{a2} \tag{3.73}$$

The total fault current flowing into the neutral is

$$I_n = 3I_{a0} = I_{bf} + I_{cf} \tag{3.74}$$

And the sequences voltages can be obtained by using Equation 3.51

$$V_{0a} = -Z_0 I_{a0}$$

$$V_{a1} = 1.0 - Z_1 I_{a1} \tag{3.75}$$

$$V_{a2} = -Z_2 I_{a2}$$

The phase voltages are equal to

$$V_{af} = V_{a0} + V_{a1} + V_{a2}$$

$$V_{bf} = V_{a0} + a^2 V_{a1} + aV_{a2} \tag{3.76}$$

$$V_{cf} = V_{a0} + aV_{a1} + a^2 V_{a2}$$

The line-to-line voltages can be obtained from

$$V_{ab} = V_{af} - V_{bf}$$
$$V_{bc} = V_{bf} - V_{cf}$$
$$V_{ca} = V_{cf} - V_{af} \quad (3.77)$$

If $Z_f = 0$ and $Z_g = 0$ then the sequence voltages become, and the positive-sequence current is found by using Equation 3.71.

$$V_{a0} = V_{a1} = V_{a2} = 1.0 - Z_1 I_{a1} \quad (3.78)$$

Now the negative- and zero-sequence currents can be obtained from

$$I_{a2} = -\frac{V_{a2}}{Z_2}$$
$$I_{a0} = -\frac{V_{a0}}{Z_0} \quad (3.79)$$

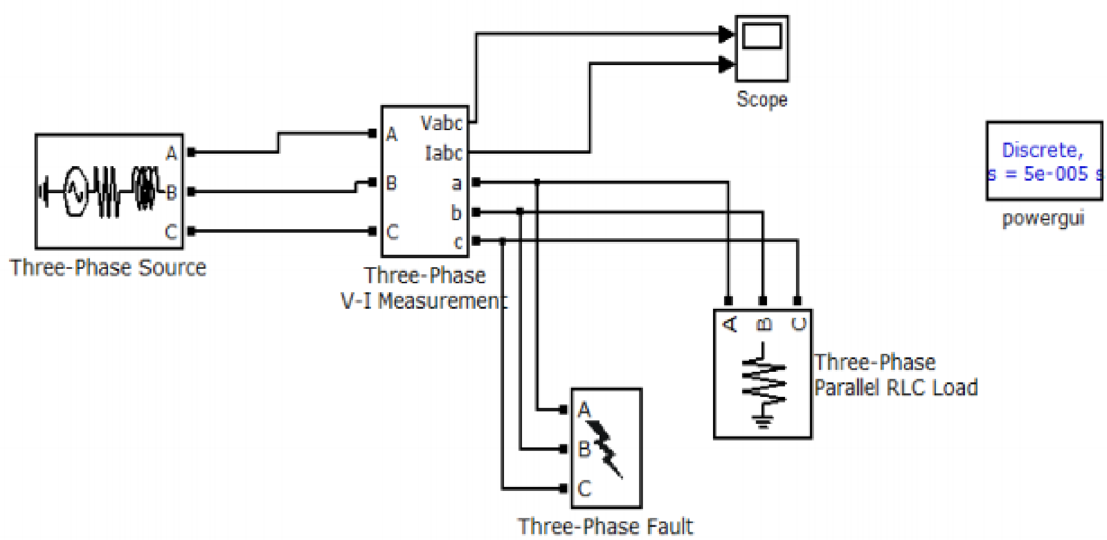
The resultant phase voltages from the relationship given in Equation 3.78 can be expressed as

$$V_{af} = V_{a0} + V_{a1} + V_{a2} = 3V_{a1}$$
$$V_{bf} = V_{cf} = 0 \quad (3.80)$$

And the line-to-line voltages are

$$V_{abf} = V_{af} - V_{bf} = V_{af}$$
$$V_{bcf} = V_{bf} - V_{cf} = 0$$
$$V_{caf} = V_{cf} - V_{af} = -V_{af} \quad (3.81)$$

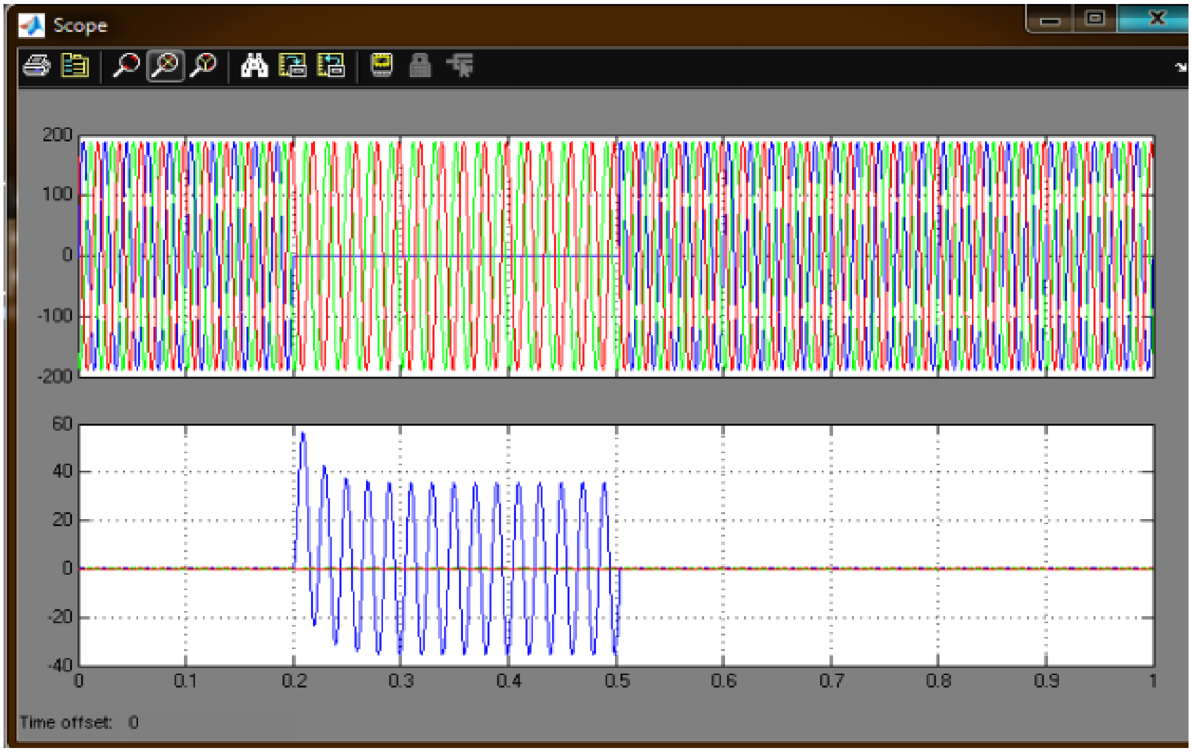
Circuit Diagram:



Procedure:

1. Open Matlab-->Simulink--> File ---> New---> Model
2. Open Simulink Library and browse the components
3. Connect the components as per circuit diagram
4. Set the desired voltage and required frequency
5. Simulate the circuit using MATLAB 6. Plot the waveforms

Graph:



Result:

A.3 Introduction to MATLAB and its basic commands

1. Introduction to MATLAB:

MATLAB is a widely used numerical computation package. It serves both as a simple calculator and as a sophisticated tool for making long complicated calculations and plot graphs of different functions depending upon requirement. Models of dynamic systems can be built easily using SIMULINK.

Some Benefits of MATLAB are:

Simple to use
Fast computations are possible
Wide working range
Solution of matrix of any order
Desired operations are performed in matrices Different Programming languages can be used Simulation is possible

To start using MATLAB/SIMULINK, open editor to create an m-file or an .mdl Simulink model in Simulink window. Always save using file names without breaks in words.

Some very important functions performed by MATLAB are:

Matrix computations
Vector Analysis
Differential Equations computations Integration
Computer language programming Simulation
2-D & 3-D Plotting

2. Basic Commands:
Some basic MATLAB commands are given as follows. Type these at the command prompt to verify.

Addition:	A+B	Subtraction: A-B	Multiplication: A*B
Division:	A/B	Power: A^B	Power of individual element: A. ^B
Range :	A: B	Square-Root: A=sqrt (B) where A & B are any arbitrary integers	

3. Basic Matrix Operations:
This is a demonstration of some aspects of the MATLAB language.

Execute the commands in MATLAB and print out the results.

Creating a Vector:
Let's create a simple vector with 9 elements called a.

```
a = [1 2 3 4 6 4 3 4 5]
a =
1     2     3     4     6     4     3     4     5
```

Now let's add 2 to each element of our vector, a, and store the result in a new vector.Notice how MATLAB requires no special handling of vector or matrix math.

Adding an element to a Vector:

```
b = a + 2
b =
3    4    5    6    8    6    5    6    7
```

Plots and Graphs:

Creating graphs in MATLAB is as easy as one command. Let's plot the result of our vector addition with grid lines.

```
plot (b)
grid on
```

MATLAB can make other graph types as well, with axis labels.

```
bar(b)
xlabel('Sample #')
ylabel('Pounds')
```

MATLAB can use symbols in plots as well. Here is an example using stars to mark the points. MATLAB offers a variety of other symbols and line types.

```
plot(b,'*')
axis([0 10 0 10])
```

Creating a matrix:

One area in which MATLAB excels is matrix computation. Creating a matrix is as easy as making a vector, using semicolons (;) to separate the rows of a matrix.

```
A = [1 2 0; 2 5 -1; 4 10 -1]
A =
  1    2    0
  2    5   -1
  4   10   -1
```

Adding a new Row:

```
A(4,:)=[7 8 9]
ans=
  1    2    0
  2    5   -1
  4   10   -1
  7    8    9
```

Adding a new Column:

```
A(:,4)=[7 8 9]

ans=
  1   2   0   7
```

```
2   5    -1   8
4  10    -1   9
```

Transpose:

We can easily find the transpose of the matrix A.

```
A = [1 2 0; 2 5 -1; 4 10 -1]
A' =
     1    2    4
     2    5   10
     0   -1   -1
```

Matrix Multiplication:

Now let's multiply these two matrices together. Note again that MATLAB doesn't require you to deal with matrices as a collection of numbers. MATLAB knows when you are dealing with matrices and adjusts your calculations accordingly.

```
A = [1 1 1; 2 2 2; 3 3 3]
B = [4 4 4; 5 5 5; 6 6 6]
C =A*B
C =
      15    15   15
      30    30   30
      45    45   45
```

Instead of doing a matrix multiply, we can multiply the corresponding elements of two matrices or vectors using the'.* 'operator.

```
C =A.*B
C =
      4    4     4
     10   10    10
     18   18    18
```

Inverse:

Let's find the inverse of a matrix

```
A = [1 2 0; 2 5 -1; 4 10 -1]
X=inv(A)
X =
     5     2    -2
    -2    -1     1
     0    -2     1
```

... and then illustrate the fact that a matrix times its inverse is the identity matrix.

```
I = inv (A) * A
I =
     1    0    0
     0    1    0
     0    0    1
```